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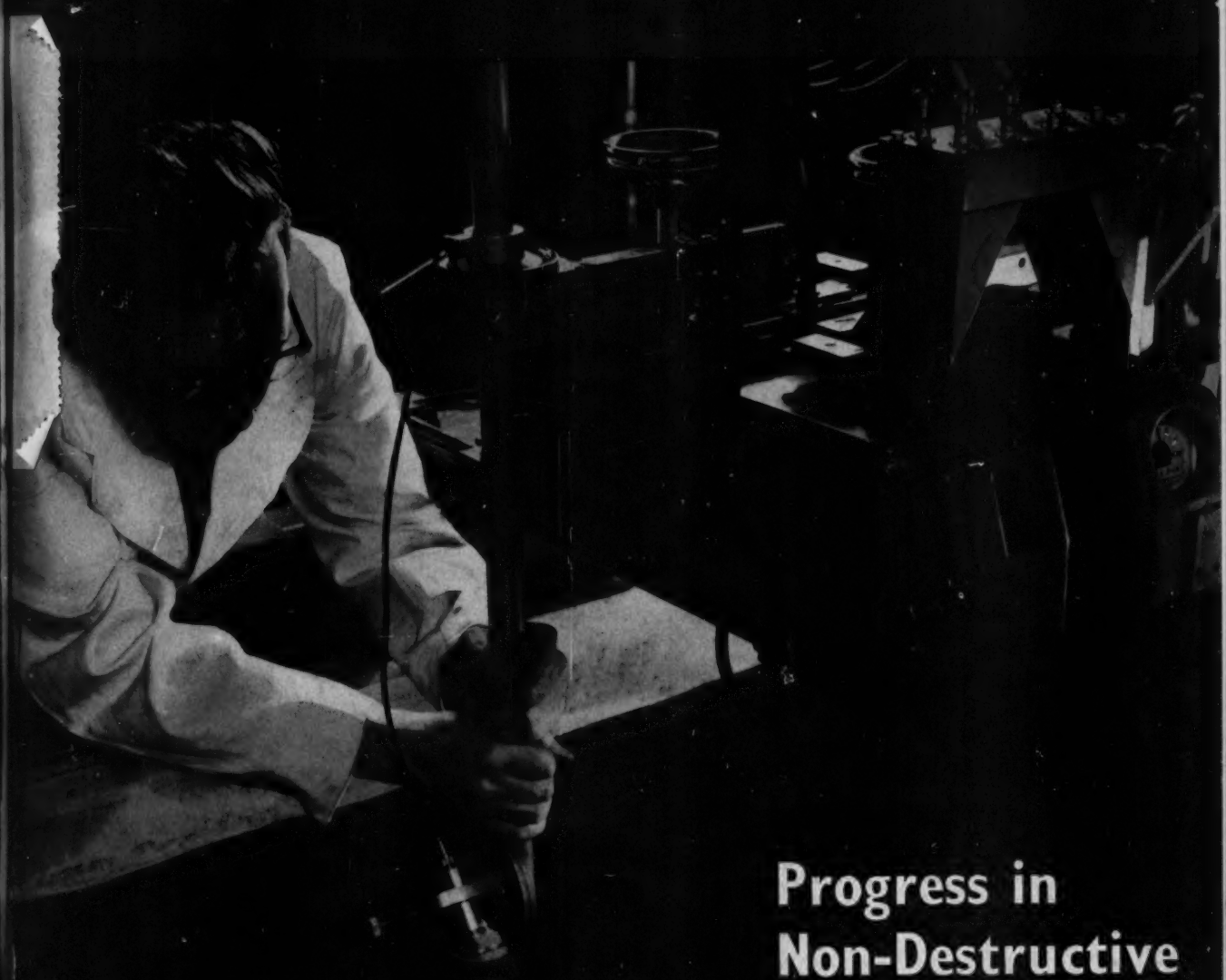

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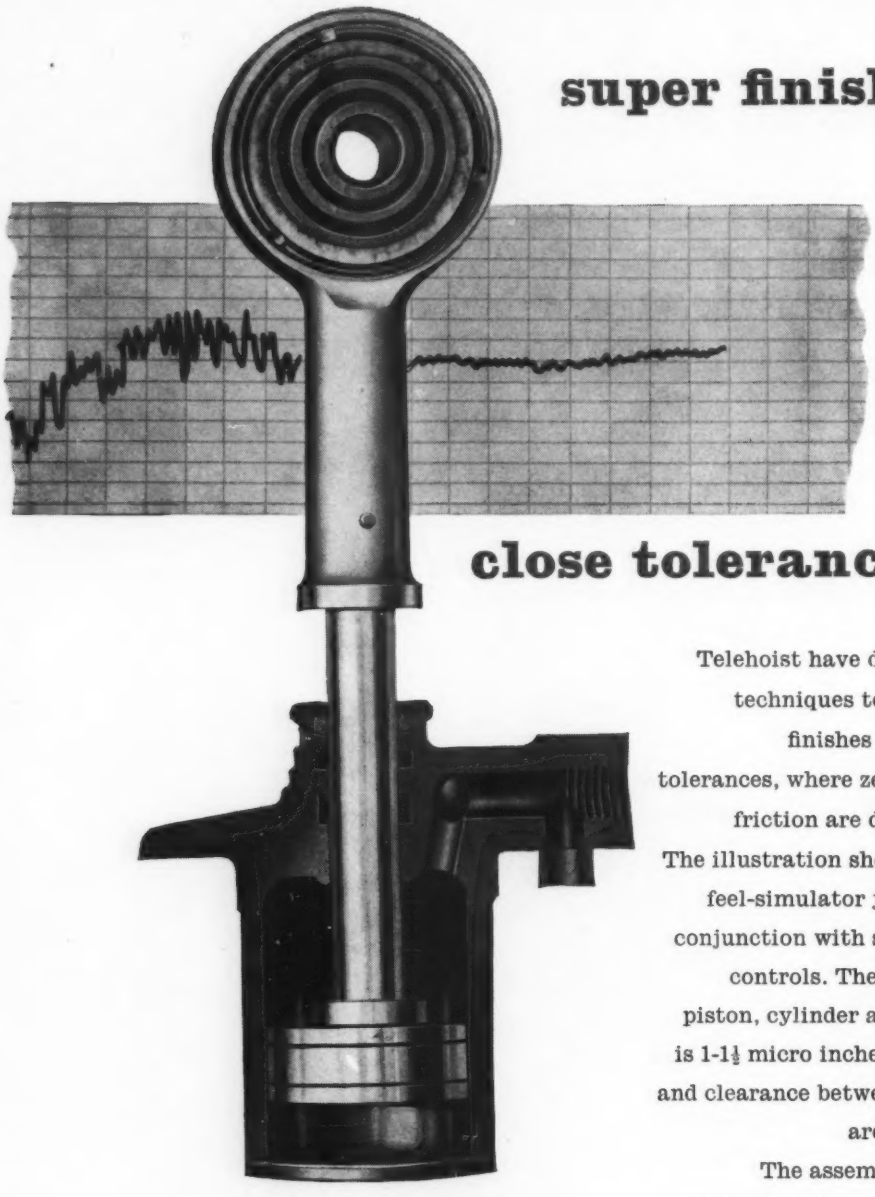
EMD 298 for further information

super finishing



close tolerances

Telehoist have developed production techniques to attain high surface finishes combined with close tolerances, where zero backlash and low friction are design fundamentals. The illustration shows an H. M. Hobson feel-simulator jack which is used in conjunction with servo operated flying controls. The surface finish of the piston, cylinder and spherical bearing is 1-1½ micro inches. The concentricity and clearance between working surfaces are within .0002 inches. The assembled units are tested at temperatures of – 40°C. and + 70°C.

If you have a production application demanding zero backlash and low friction characteristics we should be pleased to investigate and advise.

The illustration is shown by the courtesy of H. M. Hobson Limited.

Telehoist

are skilled in precision production engineering and super finishing

Telehoist Ltd, Manor Road Cheltenham, *are an associate company of Wilmot Breeden Ltd*

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★ *The Magazine for Engineering Designers*

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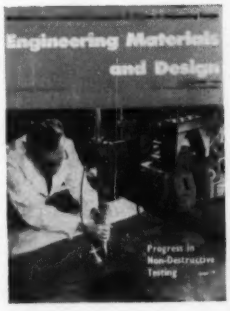
EDITOR
H. R. Heap, B.Sc., A.M.I.E.E.

TECHNICAL EDITOR
R. D. Cullum, M.I.E.D., A.R.Ae.S., M.I.A.S.

ASSISTANT EDITORS
F. R. Terrell
P. Burton



COVER—Testing with ultrasonic equipment at the Essex works of Kelvin & Hughes Ltd.

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MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Ceramic Tools

TWO USEFUL ADDITIONS to the growing literature on the performance and characteristics of ceramic tools were presented by E. J. Krabacher and J. L. Remmerswaal at the recent general assembly of the International Institution of Production Engineering Research, held for the first time in the U.K.

The researches described by Krabacher included the turning of steels, cast iron, and non-ferrous materials, and the high-speed milling of cast iron and certain non-ferrous materials such as pure nickel. A particularly interesting result was that steels such as AISI 4340 and AISI 1018 were successfully milled with ceramic tools at 2,000 f.p.m. under controlled laboratory conditions.

Good tool life was obtained with no major evidence of serious chipping. Good results were also obtained with some of the ceramic tool materials tested when milling cast iron and nickel at high cutting speeds. The results of the turning tests indicated that certain ceramic materials may give better performance than cemented carbide and cermet tools when properly applied in operations on steels, cast iron and many non-ferrous materials.

An investigation into the performance of ceramic tools when machining cast iron described by Remmerswaal was carried out at the Centre for Metalworking of the Metal Research Institute T.N.O. in Holland.

Remmerswaal showed that the particular types of ceramic cutting tool used in his main tests offer considerable advantages over cemented carbide cutting tools when turning pearlitic cast iron. But as he pointed out, there are considerable differences in the quality of tools at present available.

The results obtained both by Remmerswaal and Krabacher once more emphasise the hazards of drawing conclusions about the performance of ceramic tools in their present stage of development unless the conclusions are specifically related to the tools tested.

Corrosion of Aluminium

IN THE LAST FEW YEARS several investigators have studied the corrosion of aluminium in high temperature water; it has been shown that aluminium-nickel alloys have good resistance up to 325 deg. C. and pure aluminium has acceptable corrosion resistance up to 200 deg. C.

The main impurities in aluminium are iron and silicon and, in order to assist the preparation of a specification limiting these impurities, work has been carried out in Norway to examine the effects on corrosion of deliberate additions of iron and silicon to super-pure aluminium. The investigation showed that, depending on microstructure, alloys with less than 0.2-0.3 per cent of iron were attacked at grain boundaries; when silicon was added, a higher amount of iron was needed. Experiments on anodic polarisation suggested that the protection of aluminium is related to the anodic passivation of other metals.

Air Suspension for British Cars?

IN A RECENT ARTICLE Mr. Alan Hodgson, the general manager of Richard Berry & Son, has questioned the wisdom of British manufacturers following American trends in applying air suspension to motor cars. The main advantages of air suspension are claimed to be that it gives a softer ride, a constant periodicity and a constant height.

Of these points, the most important is comfort, for the other two can be provided by more traditional means using rubber or steel springs. Air suspension will add weight and cost to the vehicle as well as introducing extra pipework involving air-tight joints. Therefore it would appear that these disadvantages must be accepted purely to gain a softer ride, although whether this is desirable depends not only on the demand for greater riding comfort but on the type of road to be encountered. What is considered to be safe for the long and relatively straight highways of America could be dangerous on rough, twisting roads in Europe and many other parts of the world buying British motorcars. Mr. Hodgson came to the conclusion that the British motor industry is unlikely to be seriously influenced by American developments.

Inventions Wanted

IN 1957 an organisation known as The National Inventors' Council prepared a list of nearly 400 technical problems for which the armed forces of the U.S.A. were seeking a solution. By making these military needs known to industry, science and independent inventors, the council hoped to tap new sources of ideas and techniques outside the extensive government research and development programme. The council have recently published a supplement listing a further eighty problems and revising some of the previous ones. These documents make stimulating reading and should prove a valuable means of interchanging technical ideas. Examples of some interesting requirements are:—

A continuously-variable gear transmission for fire control application for positioning guns.

Internal combustion engine capable of operating in salt water.

A dielectric material for operation between −65 to +500 deg. C. and resistant to rain erosion at speeds in excess of mach 1.

A synthetic mica-like material for dielectric applications based on the inorganic silicates and composite materials combining metals and non-metals which show strength advantages at temperatures above 425 deg. C. over currently available metals and reinforced plastics.

These are only a few of the design and material problems for which the U.S. armed forces are seeking a solution. It is interesting to speculate on the benefits that might be gained if the British government were to adopt a similar procedure.

Strength of Pin-joints

TESTS carried out by the Mechanical Engineering Research laboratory on a particular type of pin-joint have shown that it can be made eight times as strong by using an interference fit for the pin in place of the original sliding fit.

The simplest type of pin-joint—a fork and tongue held together by a pin or bolt passing transversely through the assembly—is important, particularly in aeroplane construction. Direct-stress fatigue tests have been made on a high-strength aluminium alloy tongue with a hardened steel pin to improve its load-carrying capacity and to find out more about the factors which should be considered by designers. The fatigue strength of the original design was found to be much less than the theoretical value: this is thought to be due to fretting corrosion between pin and tongue.

The effect of different sizes of pin and different degrees of interference have been investigated. With a tongue 2¼ in. wide and ¾ in. thick, the best size of pin is 1 in. dia. and the best interference, for long life, is 0.007 in.

Tests are also being made on joints assembled with a sliding-fit pin in an interference-fit bush; a similar improvement in strength was obtained. These should be suitable for joints which have to be dismantled and reassembled from time to time.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN

GLASS FIBRE FAIRINGS

Making its entry into the motor-cycle field this year, Bristol Aircraft Ltd. is now producing glass-fibre reinforced plastics fairings for Royal Enfield. Wind tunnel tests were carried out to check air flow characteristics. Front cowl is moulded integrally, and the instrument panel is then bonded into position.

ULTRA-LIGHT HELICOPTER

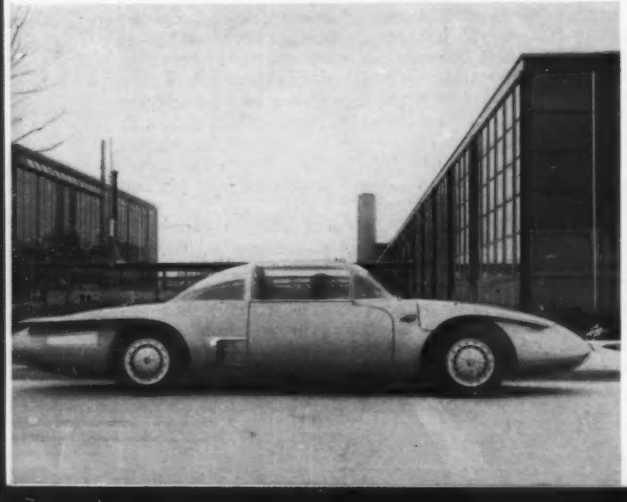
The Fairey Ultra Light helicopter, which recently went to Canada for demonstration flights, is powered by pressure jet units mounted at the tips of the two-blade rotor. These are supplied with compressed air by a Blackburn Palouste gas-turbine air generator.

ZEUS REACTOR

Removing a fuel element from the reactor core of Zeus — Zero Energy Uranium System —at Harwell. Zeus is an uncooled low-energy fast-fission breeder reactor; it has a highly-enriched uranium core (seen centre) surrounded by a natural uranium breeding blanket.

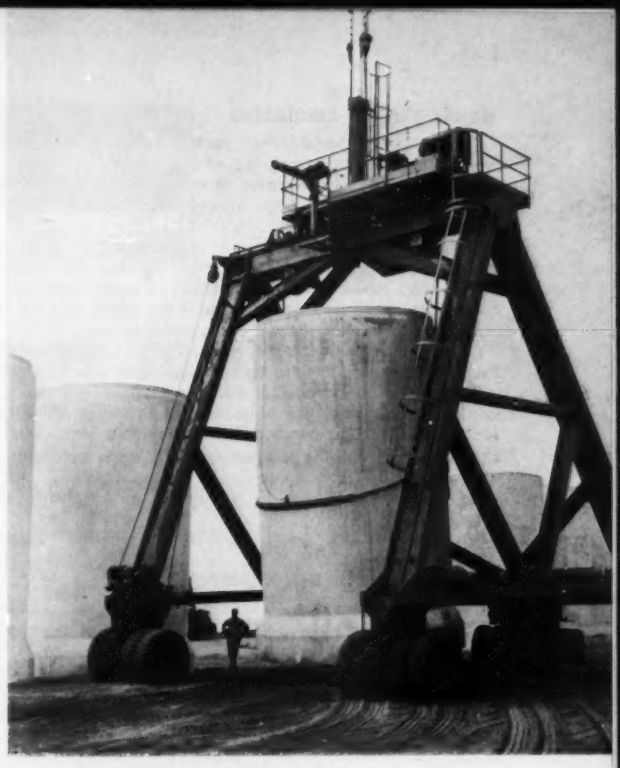
RESISTANCE HEATING

Welding with the help of nickel chrome resistance wires, insulated to withstand working temperatures of up to 800 deg. C. and covered overall with a flexible nickel alloy sheath. Made by Electrothermal Engineering Ltd., the heaters are placed about the area to be pre-heated, connected to a supply and then covered with sections of high temperature resistant lagging.



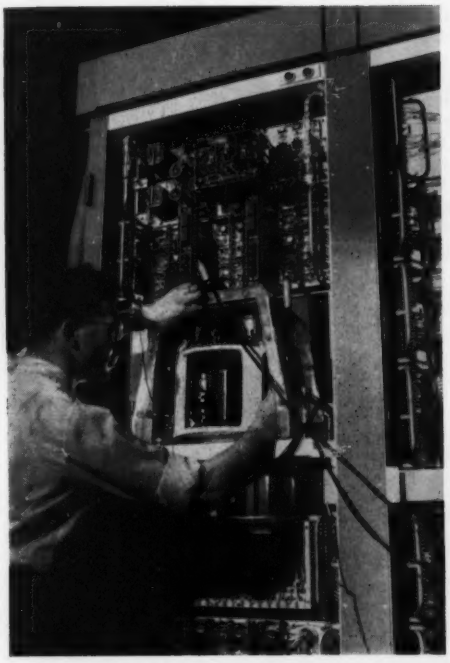
FREE PISTON ENGINE CAR

This is the XP-500, the experimental free-piston engine car built by General Motors. Four pistons in two parallel cylinders in front of the car compress air which is piped to a power turbine geared to the rear wheels.



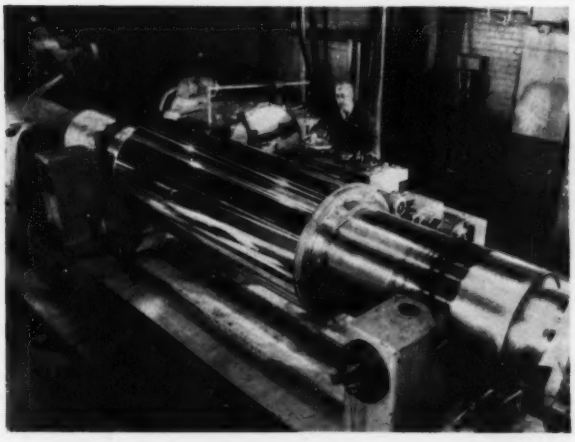
GIANT LIFTER

Carrying a 90-ton section of concrete pipe, this giant lifter-tipper has been built by the United Concrete Pipe Corp. for short-haul work at its plant in California. One man operates the hydraulic lift, which can tip its load into a horizontal position when necessary. It is drawn by a hitch-on tractor and is supported on twelve Goodrich tyres.



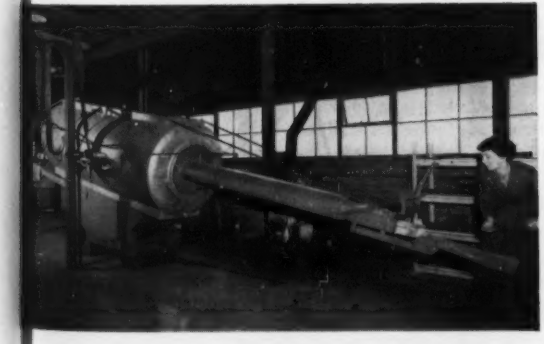
DIGITAL ELECTRONIC COMPUTER

An engineer makes final adjustments to the magnetic drum in a Deuce digital electronic computer prior to delivery. This drum forms the backing storage for the memory system of the computer which is made by English Electric Co. Ltd.



RECORD ROLL

What is claimed to be the largest fully-hardened forged steel roll made in Europe has been produced by Firth Brown. The roll, shown here, has a diameter of 36 in., is 88 in. long on barrel, and weighs 17½ tons.



SINTERING FURNACE

Daniel Doncaster & Sons Ltd. have recently developed a new powder metallurgy department at their Sheffield works. Here, an operator prepares the furnace for sintering the metals after they have been transferred from the presses.

HOUSE STYLE

This sprayer, tractor-mounted and with a special cowling to protect the driver, illustrates the programme pursued by Pest Control Ltd. to impress its identity on the public. House colours and "triple-arrow" device designed by the firm's consultant designer, characterise all products of the company.

Ready-shaped Laminates

A REDUCTION of hand lay-up work in certain reinforced plastics applications is foreseen in the announcement that three-dimensional woven-fabric laminate in a variety of shapes and sizes is now being produced here under U.S. licence by Fothergill & Harvey Ltd.

Although introduced primarily in conical shapes, the system may be applied to any configuration, symmetrical or otherwise. It may also be used in the production of honeycomb core where the weave is continuous throughout the entire section, without discontinuity of yarn at any of the nodal points.

The technique provides complex shapes of uniform thickness, a factor of paramount importance in radomes, where the dielectric properties must be considered. In addition to the accurate control of shapes, they may be held to limits of ± 0.015 in. (reduced to ± 0.002 in. where essential), and it is possible to vary the yarn sizes and to arrange their direction according to the applied load.

Similar results are said to be obtainable with yarns of glass fibre, asbestos or nylon.

Hydraulic Fluid Development

THE CORROSIVE NATURE of hydraulic fluids of the alcohol-water type has proved to be a serious disadvantage in many applications, especially when used on aircraft. The Wynadotte Chemical Corp. of the U.S.A. have developed a special corrosion inhibiting compound for the Wright Air Development Centre. This compound which is combined with the hydraulic fluid is said to prevent corrosion of aluminium alloys and steels. It is a mixture of an anhydrous methanol solution containing dicyclohexylammonium nitrate, l-nitropropane and urea.

Stress-Core

INTRODUCTION of a high-temperature stress-core by the John J. Foster Mfg. Co. of California is providing a honeycomb core which permits a more intimate bond between itself and the face material. This stainless-steel core, made in a range of wall thicknesses of between 0.001 in. and 0.004 in., derives its increased strength and stiffness from integral flanges and corrugated walls.

The cells are spot-welded together, and a special manufacturing technique permits the facing materials to be spot-welded to the core flanges. Alternative methods of attachment are by bonding adhesives or brazing, the latter being simplified by pre-coating the flanges with a brazing alloy. By using a cold-worked stainless steel, no heat treatment is necessary after spot welding.

A further interesting development which will undoubtedly have wide application is a honeycomb core with a cell size of 1/16 in. This is probably the smallest honeycomb core yet produced commercially.

Aluminium Radiators

MORE THAN 7,000 cars are at present being driven about the U.S.A. fitted with an experimental lightweight aluminium-fin radiator, which the Aluminium Co. of America is said to have been working on for twelve years.

The unit uses conventional brass tubes to carry the coolant, but weighs 20 per cent less overall than copper-finned radiators. Average installation would need about 4 lb. of aluminium, instead of 8 lb. of copper, and raw material costs are said to be about 20 per cent less than with conventional construction.

IN NEXT MONTH'S ISSUE . . .

Principal features in the February issue of ENGINEERING MATERIALS AND DESIGN will include:

Factors in Materials Selection for Low Temperatures
Effect of low temperatures on conventional materials.

Styling in Design Engineering
Integrating appearance and functional aspects.

Mechanical Shaft Seals
Survey of types and applications practice of face-type seals.

Metal Bonding with Adhesives
Its advantage over more traditional techniques.

Nickel-plated Ceramics

A PROCESS for depositing a coating of nickel on the extremities of ceramic resistance materials has been developed by Resista Fabrik Elektrischer Widerstande GmbH. The surface of the material is heated and passed through a bath of liquid nickel carbonyl; the temperature of the component is maintained at a level which will cause decomposition of the carbonyl, with resulting deposition of a coating of nickel on the ceramic.

The entrance to the vessel in which the reaction takes place is sealed, e.g., by refrigeration, and a water seal at the exit is used both to prevent exit of gas and to provide an initial rinsing system for the component. The nickel layer forms a suitable surface for soldering on the lead wires to ceramic resistors; this application is the main aim of the invention.

Stainless Intensifying Screen

THE FIRST X-ray intensifying screen impervious to chemical stains has been developed in the U.S.A.

The new screen, called the Du Pont Stainless Par Speed X-ray intensifying screen, is an improvement on the widely used Patterson intensifying screen. Because it is impervious to processing solutions, developer and fixer stains can be removed easily from the luminescent surface. On conventional screens such stains often produce confusing shadow artifacts which appear on exposed radiographs, decreasing or destroying their effective diagnostic quality.

An added feature of the screen is the unique polyester base support which replaces the conventional cardboard. The strength, flexibility, and durability which this base gives the new screen make it resistant to damage when the screen is mounted or removed from the cassette holder. Its moisture resistance prevents distortion and warping of the screen under virtually all atmospheric conditions.

Helium for Leak Detector

A FRENCH DEVELOPMENT for detecting micro-leaks down to one-hundredth of a micron uses an apparatus sensitive to helium. This gas was chosen because its molecule is very small and will penetrate very small cracks. Further advantages are its rarity in the atmosphere, and its inertness, which makes it non-explosive and non-toxic. Apart from its use in high-vacuum physics, this device would be of value to engineers for boilers, pressure vessels and electronic tubes, as well as piping accessories for the nuclear and high-pressure fields.

S.G. Cast Iron for Aircraft

CAST IRON COMPONENTS are not usually associated with aircraft design, so the lecture given by Dr. A. B. Everest at a symposium on aircraft materials, recently held at Cranfield in conjunction with an exhibition organised by the Mond Nickel Co. Ltd., was of considerable interest.

For certain components operating at temperatures for which light alloy castings would be unsuitable, S.G. cast iron can be attractive, due to its relative cheapness and the ease with which complicated shapes may be cast. Modern foundry techniques enable castings to be made with wall thicknesses as low as 0.1 in. and typical examples already used in aircraft turbine engines are bleed-off valves and rear bearings.

The symposium was the first of its kind, and included addresses on special-purpose alloys in instrumentation, and the effects of dry corrosion on high-temperature materials.

High-temperature Magnesium Alloy

A MAGNESIUM THORIUM ALLOY containing 96.3 per cent magnesium, 3 per cent thorium and 0.5-0.7 per cent zirconium has been developed in the U.S.A. by Brooks & Perkins Inc. for many applications where the extraordinary resistance to creep and excellent strength at high temperatures can be used.

For long term exposure the tensile strength at 370 deg. C. is of the order of 8,000 p.s.i. compared to 4,000 p.s.i. for usual magnesium alloys. The new alloy, known as Hk31, can be welded by normal commercial methods developed for other magnesium alloys, and it also possesses fine machining properties. It is being used in the form of sheet, extrusions and castings for high-speed aircraft and for surface-to-air missiles.

Engineering Materials and Design

PLASTICS COMPLEMENTARY TO METALS

THE view is expressed in some quarters that plastics are now challenging metals as engineering materials. Traditionally, the basic raw materials for the engineering industry are metals such as iron, steel and brass, but in 1957 the production of plastics in Britain was over 400,000 tons, much of it for engineering.

There is little doubt that in certain specialised fields, such as motor vehicle bodies, corrosive fume exhaust equipment and high-speed missile parts, plastics have been able to compete with metals by virtue of their light weight, their resistance to corrosion and the ease with which they can be formed into intricate shapes. Although many possible outlets for the use of plastics have been blocked by their relatively high cost, the price of the raw materials has fallen steadily since the war. This factor may have provided an additional incentive to make use of plastics, although it would appear that the raw material prices will not drop much lower, except possibly in the case of polyethylene for which greatly increased production is planned.

It is evident that engineers are beginning to appreciate the value of plastics, not only for their insulating and corrosion-resisting properties, but as basic materials for construction. The rapid developments in reinforced plastics have particularly emphasised the widening scope for these materials in engineering and the ever-growing demand for performance data suggests that designers are taking a serious interest in this work. At the present time there is a dearth of reliable information on these materials, partly because developments have been very rapid and long-term durability tests are not yet completed, and partly on account of the great influence which the processing and fabricating methods exert on the final product.

At first glance, therefore, it would appear that a relatively young and virile plastics industry is likely to become a threat to the older established iron and steel industries. However, the increased production of plastics must be considered in relation to that of metals; for instance, steel production in this country increased by over seventy per cent between 1947 and 1957, and part at least of the plastics industries' expansion is due not to an encroachment on metals but to the general increase in industrial activity.

A closer inspection of the situation reveals a not unsatisfactory position for both industries. It is, perhaps, unfortunate that really large-scale production of p.v.c. and polyethylene as well as tremendous development activity with reinforced plastics should coincide with a slight fall in demand for metals due to the recent slowing down of trade generally. It is natural that any form of competition will hurt most at times like these.

In heavy engineering it seems unlikely that plastics will replace metals to a serious extent, but, undoubtedly, small specialised components such as nylon gears will contribute to improved designs and can, therefore, be considered to assist the sale of metal products. In the motor vehicle industry some spectacular technical achievements have taken place in the replacement of body panels by glass-fibre reinforced plastics, but for the important production of passenger car bodies this does not appear to be a commercial proposition except for a few cars produced in small numbers. Similar arguments hold for production of railway rolling stock.

A degree of competition is healthy in any industry and the fact that discussion is taking place at the present time between the relative merits of plastics and metals will almost certainly result in benefit to both. Some changes over to plastics will certainly take place during the next ten years and a degree of readjustment will be necessary on the part of both metal producers and engineering designers, but there is no indication that a revolutionary change will make metals obsolete. Developments in plastics have tended to be spectacular and, therefore, are liable to receive publicity out of proportion to their commercial significance. Developments in metals, on the other hand, have not always received enough attention and mistakenly it may be thought that little is being done in this direction. In fact, quite the reverse is true, for metallurgical progress has never been more rapid than at the present time and it is only necessary to look at the new high-temperature nickel alloys, the widening scope for stainless steels and the commercial exploitation of the rarer metals such as titanium and beryllium to see that the metal industry is very much alive to the situation.

Metals and plastics are clearly complementary, each fulfilling certain requirements. Research is already bringing the two closer together for production of composite materials such as "plasteel", a p.v.c. continuously-bonded steel strip, developed by the British Iron and Steel Research Association. Another attempt to embody the advantages of plastics in combination with steel is electrophoresis, now being studied as a potential means of applying resins and metallic oxide coatings to steel, and this process is believed to be advantageous in the application of organic coatings to strip steel at high speeds. Constant research is going on into new bonding materials, by means of which steels can be used as a backing for corrosion-resistant plastics or light alloy metals. Lastly, powder metallurgy is in a state of hectic experiment to develop an increased number of products in which metallic particles having special properties are embedded in a plastics matrix or bonded with plastics.

SPECIAL-PURPOSE FASTENERS

For load carrying, for quick assembly and release, for fixing blind panels—these are some of the principal purposes for which a variety of special fastening devices are available. This article examines advantages offered by each group

Fig. 1. A Dzus deck fastener.

SPECIAL fasteners are of great importance in industry and have wide applications where quickly-detachable panels are required and where for economy in design, it is necessary for these panels to act as load-carrying members.

Prior to the introduction of these fasteners, the usual method of securing detachable panels was by using nuts and bolts, which not only take time in the initial assembly stages, but also increase maintenance time when the panels need to be removed. This reduction of maintenance time is all-important for transport vehicles and machinery in which the duty cycles must be at a maximum.

With these criteria is the need for fasteners which do not require access from both sides of the panel. Captive nuts are an example of a method to achieve this end.

To summarise the various types of fastener, it is desirable to group them into the following categories:

(a) For load carrying and quick release.
(b) For rapid initial assembly and which carry incidental loads.
(c) For insertion from one side of a panel.

Designs in the last category are often inherent in the first two.

In all these fasteners it is important that due regard is paid to their structural application and to the method of their attachment. If these demand a high-precision fit, problems in production may arise, particularly if a number of fasteners are used in any one panel and these are to be interchangeable.

In many types of fasteners the applied load is limited by the rivets or attachments holding the body of the fastener in position, and this must be taken into consideration when evaluating the strength of the fasteners. To overcome this difficulty, fasteners are often provided with a spigot which projects into the structure, thus relieving the load on the attachments.

In assessing the loads to be imposed on a fastener, account must be taken of its deflections, which may well be the limiting factor rather than the ultimate loads which the fastener will carry.

Many of the proprietary brands of fasteners can be adapted for special purposes and cover a range of sizes and loads. These fasteners are classified in tabular form on pages 12 and 13 so that their particular features may be seen at a glance, further information being available from the manufacturers. To facilitate the correct fitting of these fasteners, a range of special tools is available.

Many of the special fasteners associated with domestic and light industrial equipment have been omitted from the table, since these are primarily used for fastening one or more parts together and carry only incidental loads. Some of these are ingenious from their design aspect, either as a blind attachment or as a self-locking type. In industries employing this type of fastener, the criterion is usually the need to reduce assembly time and thus labour costs, which are, of course, a predominating factor. In this category one of the best-known types of fastener is the Spire speed nut marketed by Simmonds Aerocessories Ltd., and which is available in a wide variety of shapes and sizes to suit almost any design configuration.

In addition, there are a variety of standard-type nuts fitted with a device enabling them to be self-locking. This often takes the form of an insert of a fibrous material or nylon in which the thread is generated when the bolt is inserted. This principle is also applied to bolts which screw into threaded holes in components, as, for example, the G.K.N. Wedglok. Other types of self-locking nuts are designed such that the thread pitch is displaced over a small part of the threaded portion, with the result that this portion will tightly grip the threads of the bolt or screw. In using these self-locking bolts and nuts, consideration must be given to their design when they are to be used again after removal, as the material used for the insert, when cut by the encompassing thread, may be insufficiently elastic to grip tightly, thus losing the full locking effect.

Fasteners in the broad sense also would include rivets, and in this category the blind type of rivet is of importance. The best known that are available are the Chobert and Avdel (Aviation Developments Ltd.) and the Tucker Pop and Imex rivet (Tucker Eyelet Co. Ltd.), where the basic principle of expanding the projecting shank from the head side of the rivet is used. The explosive rivet is quite different, since the expansion of the shank is performed by a small explosive charge contained in a cavity at the end of the shank. While these rivets have the advantage of a solid shank at the bearing surfaces of the materials to be joined, the products of combustion may set up a corrosive action.

DZUS FASTENERS—These are available in various sizes

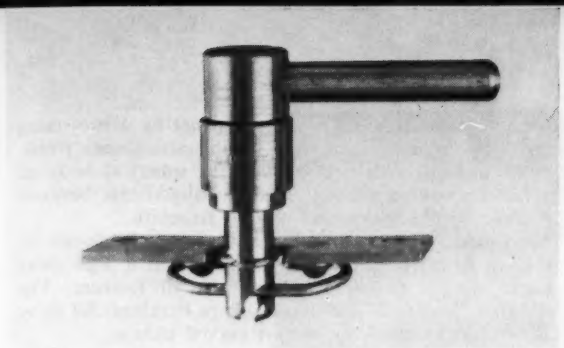


Fig. 2. Dzus instrument racking fastener.

Fig. 3. Typical application of Dzus fasteners for instrument panel of Vauxhall Bedford van.

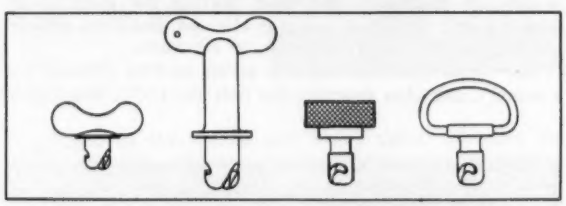


Fig. 4. A few of the various head formations used in Dzus-type fasteners.

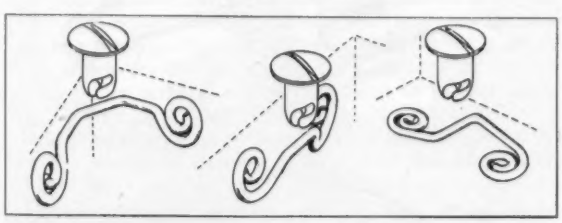


Fig. 5. Various locking springs of Dzus fasteners indicating their use in confined spaces.

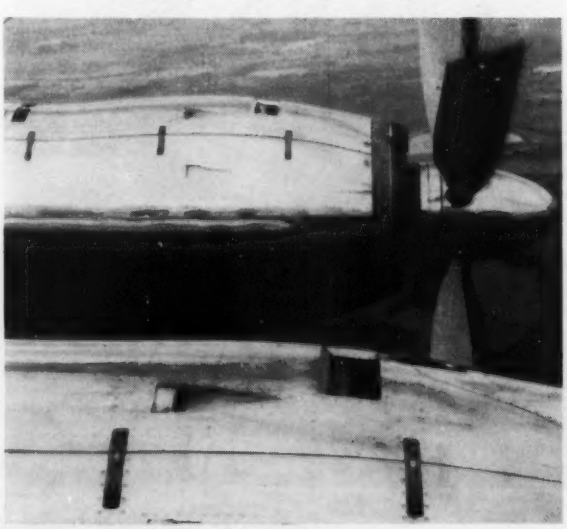


Fig. 6. King Arctic toggle fastener used on Dart turbine engine installations.

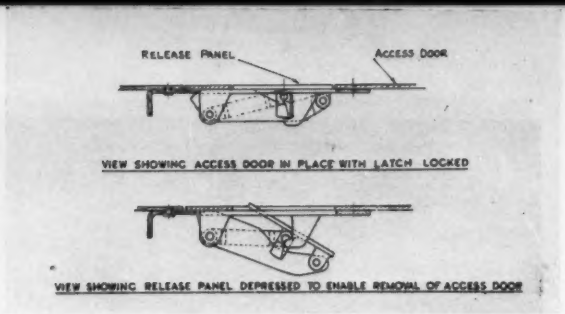

RELEASE PANEL
ACCESS DOOR
VIEW SHOWING ACCESS DOOR IN PLACE WITH LATCH LOCKED
VIEW SHOWING RELEASE PANEL DEPRESSED TO ENABLE REMOVAL OF ACCESS DOOR

Fig. 7. Method of installing King flush-fitting panel latch.

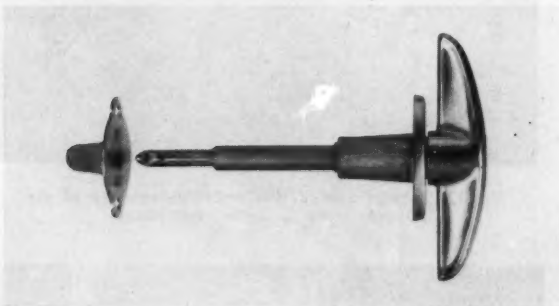


Fig. 8. Oddie fastener with chromed handle used on refrigerators.

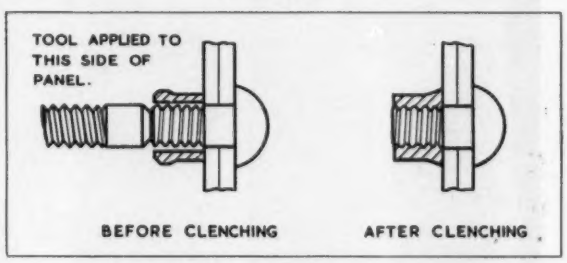


Fig. 9. Avdel Lockbolt before and after clenching retaining collar.

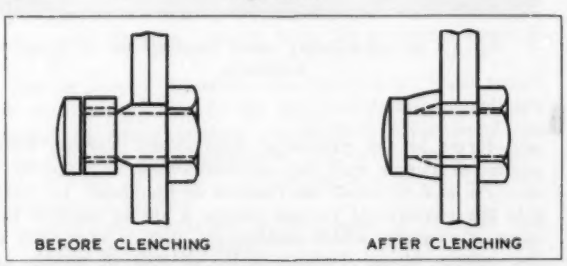


Fig. 10. Avdel Jo-bolt before and after clenching collar.

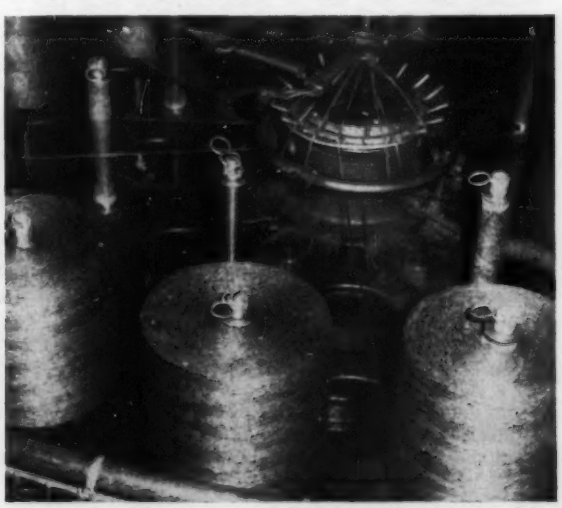


Fig. 11. Typical application of Pip-pin made by Aviation Developments Ltd. to secure yarn bobbins.

Fig. 12. Jo-bolts used in the undercarriage bay of the Sud-Aviation Caravelle mainplane.

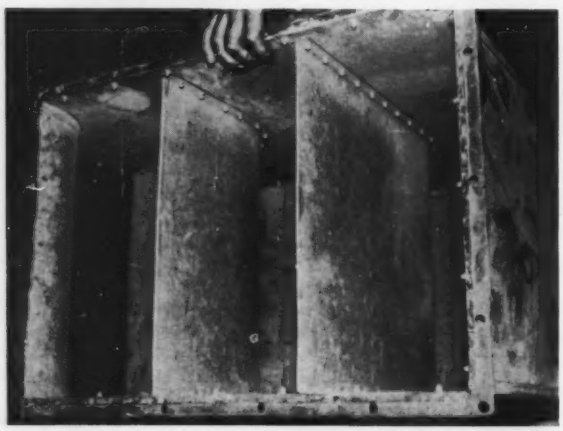


Fig. 13. Air-conditioning trunk showing use of Avdel Lockbolts.

and forms to suit particular applications. Various thicknesses of panels may be accommodated and grommets may be used to retain the fastener in the panel. To facilitate the removal of curved panels, a spring ejection fastener is available which ensures the stem is kept clear of the bottom fitting. Various forms of locking springs are available which may be used in a confined space, such as in the corner of a box.

The standard range of fasteners is more suited to lightly loaded structures. Where the loading is combined shear and tension, the flush-head tension fastener or the supersonic fastener should be used. The multi-fastener strip using panel-attachment-type fasteners at pitches arranged to suit particular requirements obviously offers considerable advantages, especially for instrument mountings.

THE ODDIE FASTENER—This employs a flat metal spring for the retention of the fastener body, and a variety of head shapes are available together with different lengths of shank to suit panel combinations. The design incorporates a flexible rubber washer which prevents chattering between the joined parts and the accidental loss of the fastener body. Where these fasteners are subjected to a high temperature, the rubber washer may be replaced by a coiled metal spring.

In addition to the standard range of fasteners, the Oddie Solidlock is designed for carrying high loadings in both shear and tension and are so designed that the shear loads are transferred from the top panel by a projecting spigot, thus relieving the load on the attachment rivets. The shear load is carried through the spherical body of the fastener which permits small misalignments between the plane of the panel and seating structure.

CUSTODIAN AND STRONGHOLD FASTENERS—Produced by the King Aircraft Corporation, these permit a high shear transfer with a minimum overall size of fastener. The Custodian fastener is also obtainable in titanium. All these fasteners ars suitable for use on curved panels.

In addition to the standard range of fasteners, the Arctic flush-fitting panel latch has numerous applications where it is necessary for it to be operated with a heavily gloved hand. The actuation of the latch is positive and so designed that, when flush with the panel, it is safely locked. The Arctic cowling fasteners are made specifically to fit flush within curved panels (either convex or concave), and may be used under similar conditions as the panel latch.

AVDEL BOLTS—Aviation Developments Ltd. produce many fasteners designed for easy assembly. Among these is the Avdel Jo-bolt, an example of a high-strength attachment which can be inserted from one side only and is known as a blind attachment. These may be obtained with either hexagonal or countersunk heads and consist of an inner screwed mandrel which, when drawn up by the driving tool, expands the pre-attached nut over the tapered end of the bolt. At a predetermined torque the mandrel breaks off flush with the head, leaving the parts to be joined tightly clenched, and it is claimed that these attachments provide a high resistance to vibration.

The Avdel Lockbolt requires access to both sides of the assembly, and after inserting the bolt, the protruding shank

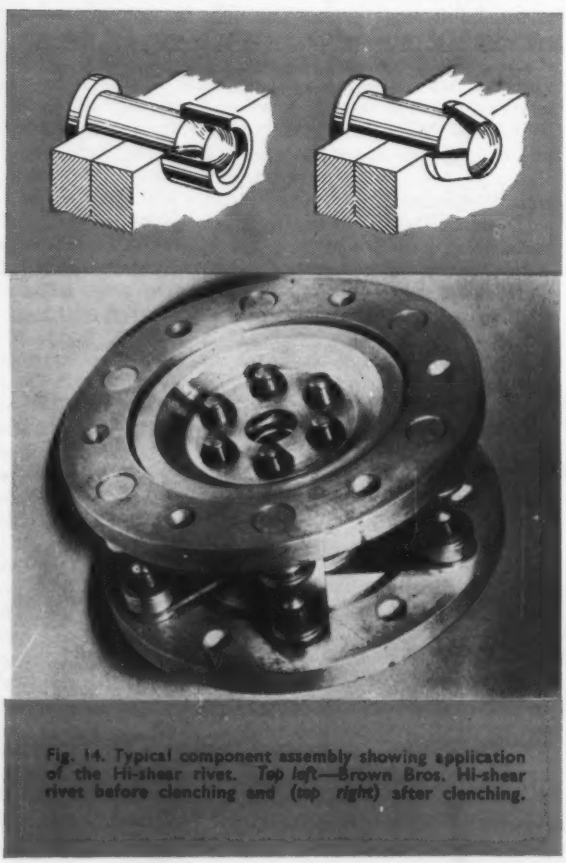


Fig. 14. Typical component assembly showing application of the Hi-shear rivet. *Top left*—Brown Bros. Hi-shear rivet before clenching and (*top right*) after clenching.

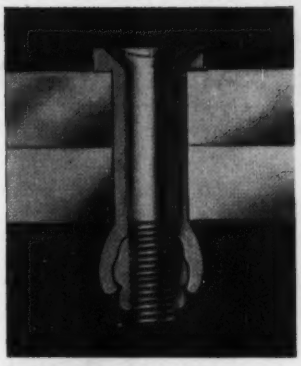


Fig. 15. Hi-shear blind bolt in position after shank has been expanded.

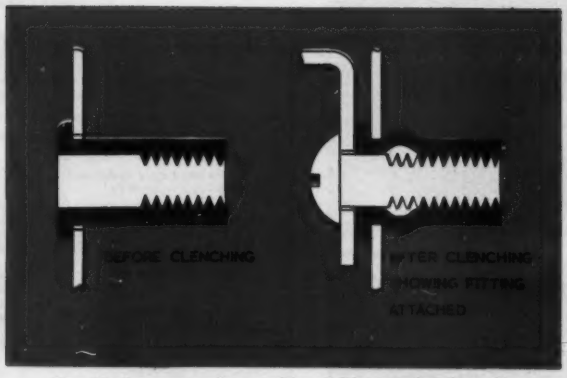


Fig. 17. Sequence of assembly of Rivnut, showing effect of shank expansion, for use in blind holes.

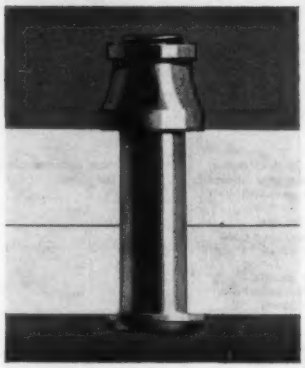


Fig. 16. Hi-lok fastener with controlled torque nut, shown assembled.

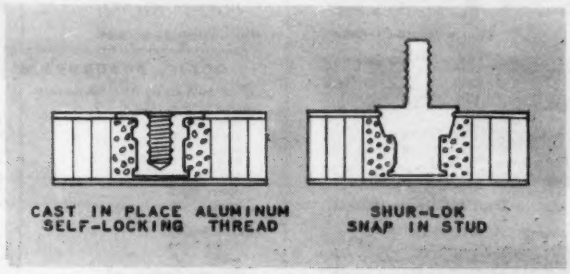


Fig. 18. Typical Shur-lok potted-in fasteners used for sandwich panels, showing the extent of bonding resin.

is gripped by the special tool which tightly clenches the plates and swages the loose collar into the locking grooves in the bolt. At a predetermined torque the protruding shank breaks, leaving the bolt permanently fastened.

The Pip-pin series of attachments are positive-lock, quick-release pins and are obtainable in various diameters and lengths with widely differing head formations. After inserting, the pin is restrained by two diametrically-placed balls which are forced beyond the periphery of the pin shank by an internal mandrel operated by a plunger or ring in the head of the pin.

THE HI-SHEAR RIVET—This is a further version of the clinch-nut type of fastener marketed in this country by Brown Bros. (Aircraft) Ltd. in which the nut is replaced by a collar. Under pressure from the tool, the collar deforms into a groove at the end of the shank and these fasteners offer a considerable advantage over normal rivets, since they are able to resist tension loads. Manufactured in light alloy, steel and titanium, they are available in standard ranges and over-sizes, the latter being used where holes have inadvertently become enlarged.

HI-SHEAR RIVET TOOL CO.—This company is producing a range of blind bolts and nuts in which the protruding shank is expanded by a threaded expander nut which resists installation torque and locks the core bolt in place, at the same time expanding the outer sleeve to fill a hole over a large range of clearances. When thus installed it has excellent vibration-resistant qualities.

The Hi-lok fastener is a consistently-controlled preloaded fastener in which the retaining collar, after being tightened to the appropriate preload value, shears from the wrenching nut.

THE RIVNUT—An ingenious light-alloy blind attachment which expands on the blind side when the bolt is tightened up. Special tools are available to facilitate the operation of upsetting the smaller-diameter Rivnuts.

THE SHUR-LOK—This range of fasteners has been specially developed for use in sandwich materials, and the strength of each type of fastener is limited by the strength of the sandwich itself. The increasing use of sandwich panels as a constructional material calls for easy means of securing both panels and fittings. A typical value for tension pull-out of the SL.1 series in an aluminium alloy honeycomb panel of $\frac{1}{4}$ in. cell size and 0·625 in. thick with face panels of 0·020 in. thickness is 695 lb. The shear value or edge bearing value in a similar panel is 1,252 lb.

The fasteners fall broadly into two groups, those which are mechanically held in the panel, and those which are bonded, the latter offering no problem if the panel has been pre-cured in manufacture. The procedure for "potting in" the SL.1, SL.2, SL.78 series type of fasteners should be as follows:

1. Drill and counterbore hole in panel to diameter and depth to suit fasteners.
2. Deburr and remove all swarf.
3. Fill hole approximately 75 per cent with suitable resin.*
4. Place insert in hole until flush with face panel and wipe off excess resin.

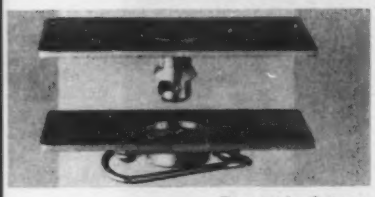
The snap-in insert is also "potted in", but allows the face panel to fit in a machined groove, the head of the insert protruding approximately 0·005 in. This type is available either as a stud or as an insert to accommodate a bolt.

The SM and SN series are two-part assemblies available with a flat or countersunk head. Each part is interchangeable so that a flat head grommet may be used with a countersunk head ferrule and vice versa.

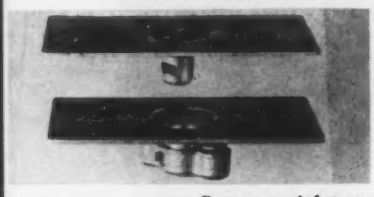
In addition to the standard ranges, all fasteners may be specially made to suit either a particular requirement or with a particular thread formation, the standard ranges using threads to either S.A.E. or U.S. form unless otherwise stated.

* Suppliers recommended by Shur-Lok Corp.: C.I.B.A. (A.R.L.) Ltd. and Shell Chemical Co.

Dzus dome-head fastener.



Dzus tension fastener.



Dzus supersonic fastener.

Dzus self-ejection fastener.

Dzus panel-mounting fastener.

Oddie standard dome-head

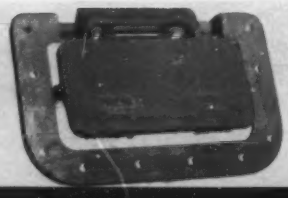
Oddie Solidlock type 936.

Solidlock, 756, 877, 885, 888, 896 and 948.

King Custodian fastener.

King Stronghold.

King Arctic panel latch (*below*).

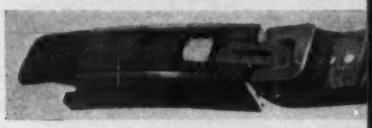


LOAD-CARRYING FASTENERS AVAILABLE TO INDUSTRY.

Type	Nominal Size (in. dia.)	Ultimate Shear Load (lb.)	Ultimate Tensile Load (lb.)
DZUS FASTENERS EUROPE LTD.			
Standard			
Dome head type A-AJ, and flush head, type F-FJ	1/4		350
	5/16		700
	3/8		1,000
	7/16	Shear values	1,250
	1/2	depend on	1,500
	9/16	nature of application.	1,800
Flush head, type FA	5/16		1,000
	3/8		1,500
Csk. hexagon head, type HF	7/16		1,800
Self-ejection, type EF	5/16	360	1,000
	3/8	600	1,250
Supersonic fastener (dome, flush and wing head)	7/32	300	300
	5/16	750	750
	3/8	1,050	1,050
Tension fastener (flush head, type TCF)	5/16	1,500 (working load)	1,500 (working load)
	3/8	2,000 (,, ,,)	2,000 (,, ,,)
Panel mounting fastener	7/32	150	200
ODDIE, BRADBURY & CULL LTD.			
All in mild steel. Also obtainable with knurled head.			
Oddie Standard			
dome head	3/8 in. dia. clearance hole in panel	Not recommended for shear	500-550
wing ,,			180 (working load)
flush ,,			
Oddie Midget	1/4 in. dia. clearance hole in panel	,,	210
dome head		,,	70 (working load)
wing ,,			
flush ,,			
Oddie Atom	3/16 in. dia. clearance hole in panel	,,	60
dome head			20 (working load)
wing ,,			
Oddie Solidlock			
Type 756 flush head (H.T.S.)	3/8 in. dia. hole in panel	5,000	4,745
Type 848 (H.T.S.)	11/16 in. dia. hole in panel	10,260	4,745
Type 888 flush head (H.T.S)	11/16 in. dia. hole in panel	10,260	4,745
Type 936 (retractable) (H.T.S.)	3/8 in. dia. hole in panel	5,000	3,200
Type 948 flush head (light alloy)	11/16 in. dia. hole in panel		
Type 885 flush head (retractable) (H.T.S.)	,,	10,260	4,745
Type 896 flush head (H.T.S.)	,,	10,260	4,745
Type 877 flush head (retractable) (H.T.S.)	,,	10,260	4,745
KING AIRCRAFT CORPORATION LTD.			
Custodian fastener (flush fitting and suitable for curved panels)	Size 1	4,000 (H.T.S.)	1,700 (H.T.S.)
		3,200 (titanium)	1,400 (titanium)
	2	6,000 (H.T.S.)	3,000 (H.T.S.)
		5,000 (titanium)	2,500 (titanium)
	3	9,000 (H.T.S.)	4,000 (H.T.S.)
		7,600 (titanium)	3,200 (titanium)
(External attachment pad on outer panel)	Type B	3,000	3,000
Stronghold fastener	Size 1	3,200	1,400
	2	5,000	2,500
	3	7,600	3,200
Arctic flush panel latch			Ultimate load normal to plane of panel 730 lb.
Arctic Cowl fastener	Junior (sizes to suit curved panels of radii 12, 24, 40 in. (convex) and 40 in. (concave) and for flat panels)	2,000	2,000
	Heavy duty (sizes to suit curved panels of radii 27, 40, 56 in. (convex), 27 in. (concave) and for flat panels.)	9,000	7,000 tension 1,200 compression
AVIATION DEVELOPMENTS LTD.			
Jo-bolts	1/4	2,450	2,250 approx.
(hex. and csk. head)	5/16	4,200	4,100 approx.
	3/8	—	—
			Tensile values depend on application.
Avdel lockbolts	3/16	2,200 (steel)	2,150 (steel)
(brazier and csk. head)		1,350 (light alloy L.64)	1,100 (light alloy L.64)
		950 (,, ,, NR.6)	700 (,, ,, NR.6)
	1/4	3,600 (steel)	3,300 (steel)
		2,300 (light alloy L.64)	2,100 (light alloy L.64)
		1,600 (,, ,, NR.6)	1,125 (,, ,, NR.6)
Pip-pins	1/4	3,260 Calculated single	—
	5/16	5,470 shear loads.	—
	3/8	7,950	—
	7/16	10,800	—
	1/2	14,400	—
	9/16	18,300	—
	5/8	22,600	—
	3/4	32,700	—
	7/8	45,200	—
	1	58,400	—

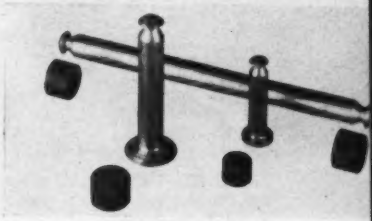
Type	Nominal Size (in. dia.)	Ultimate Shear Load (lb.)	Ultimate Tensile Load (lb.)
LINREAD LTD.			
Rivnuts			
Flat head	4 B.A.	250 single shear	800
	2 B.A.	360 " "	1,300
	¼ in. B.S.F.	630 " "	3,130
	5/16 in. B.S.F.	1,150 " "	4,250
	⅜ in. B.S.F.	1,375 " "	4,500
Csk. head 90 deg. (for panels of total thickness)	4 B.A.	310 " in dimpled csk.	800
	2 B.A.	510 "	1,300
	¼ in. B.S.F.	630 "	3,130
	5/16 in. B.S.F.	1,150 "	4,250
	⅜ in. B.S.F.	1,375 "	4,500
	Also available with Whitworth threads ¼, 5/16, ⅜, 7/16 and ½ in.		
BROWN BROS. (AIRCRAFT) LTD.			
Hi-shear rivets (Flat and csk. head and dowel pins) (Available in S.S., Monel, aluminium alloy, and 55/56 and 86 ton steel)	¼ 5/16 ⅜ 7/16 ½ 9/16 ⅝ ¾	Shear values comparable to bolt strength.	1,380 2,440 3,574 Typical values using light alloy collars.
HI-SHEAR RIVET TOOL CO.			
Hi-lok fasteners (pan head and csk. head) (Available in alloy steel type 4130 and stainless steel type 431 (U.S. specs.), and titanium and aluminium)	7/16	Dependent on material and comparable to bolt shear value	1,800 (pan head) 1,900 (csk. head)
	½		3,500 (pan head) 3,400 (csk. head)
	9/16		5,600 (pan head) 5,500 (csk. head)
	¾		8,300 (pan head) 8,000 (csk. head)
Blind bolt (in stainless steel) Flat head BB 352 series	7/16	4,231	1,804
	½	5,487	2,275
	9/16	9,785	4,614
	⅝	15,633	7,574
	¾	21,307	8,849
Csk. head, BB. 351 series	7/16	4,231	1,870
	½	5,487	2,500
	9/16	9,785	4,274
	⅝	15,633	7,220
	¾	21,307	9,947
SHUR-LOK CORPORATION			
Self-locking insert SL.1 (in M.S., H.T.S. and S.S.)	Thread sizes 0·164 in. dia. (32 t.p.i.), 0·190 in. dia. (32 t.p.i. and ¼ in. dia. (32 t.p.i.). Lengths for sandwich thickness of ⅛ to 2 in.		
Snap-in insert SL.2 (in M.S., H.T.S. and S.S.)	Thread sizes as SL.1 Lengths for sandwich thickness ⅛ to ⅜ in.		
Self-locking insert (lightweight model SL.78 (in M.S., H.T.S. and S.S.)	Thread sizes 0·164 in. dia. (32 t.p.i. and 0·190 in. dia. (32 t.p.i.). Lengths for sandwich thickness ¼ to 5/16 in.		
Self-locking shear fastener SL.7 (in M.S., H.T.S. and S.S.)	Thread sizes 0·164 in. dia. (32 t.p.i.), 0·190 in. dia. (32 t.p.i.) and ¼ in. dia. (32 t.p.i.). Lengths for sandwich thickness ¼ to ⅜ in.		
(Types SL.1, SL.2 and SL.78 for potting-in.)			
Kwiko spacer SL.20 (in light alloy)	Thread sizes 0·190 in. dia. (32 t.p.i.) and ¼ in. dia. (28 t.p.i.). Lengths for sandwich thickness 5/16 to 1 in.	Ultimate loads depend on the strength of sandwich panel.	
Kwiko spacer for csk. head bolts SL.21 (in light alloy)	Sizes as for SL.20		
Thru-spacer SM series (flush or flat head—in M.S., H.T.S. and light alloy)	Hole sizes 0·144, 0·167, 0·194 and 0·252 in. Lengths for sandwich thickness ⅛ to 1 in.		
Threaded spacer SN series (flush or flat head, available with or without self-locking feature; in M.S., H.T.S. and light alloy)	Thread series 0·138 in. dia. (32 t.p.i.), 0·164 in. dia. (32 t.p.i.) ¼ in. dia. (U.N.F.) and 0·190 in. dia. (32 t.p.i.). Lengths for sandwich thickness ⅛ to 1·0 in.		
Stud SS series (flush or flat head—in M.S., H.T.S. and light alloy)	Thread sizes 0·164 in. dia. (32 t.p.i.), 0·190 in. dia. (32 t.p.i.), 5/16 in. dia. U.N.F., ⅜ in. dia. U.N.F., ¼ in. dia. U.N.F. Lengths as required.		

King Arctic Junior.

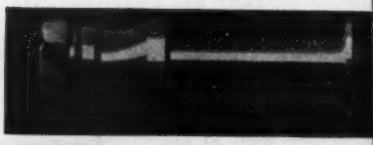


King Arctic Heavy-duty.

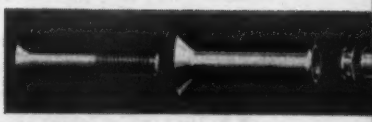
Avdel lockbolt (*top*); Jo-bolt (*left*); Pip-pin (*right*).



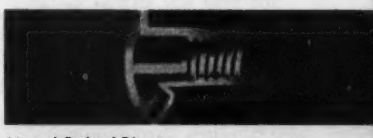
Brown Bros. Hi-shear dowel pin (*background*); csk. head (*left*); pan-head (*right*), with collars.



Hi-lok fastener.



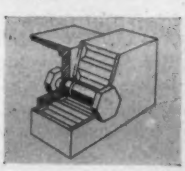
Hi-shear blind bolt BB 351.



Linread flathead Rivnut.

Shur-lok insert SL.1.

Shur-lok snap-in insert SL.2.

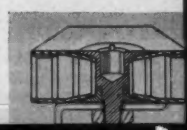


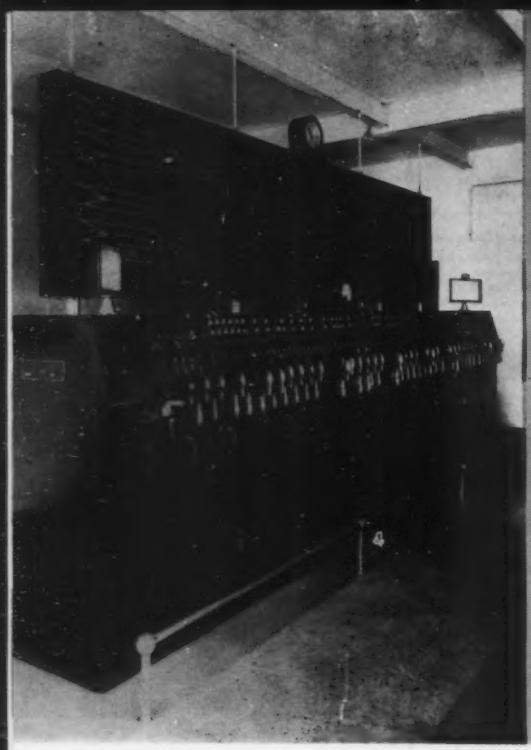
Shur-lok shear fastener.

Shur-lok Kwiko spacer.

Shur-lok Thru-spacer.

Shur-lok stud SS series.





Metropolitan-Vickers' signalling frames before and after redesign. The new design has greater visual appeal, as well as meeting user requirements which have been formulated by research.

APPEARANCE VITAL IN INDUSTRIAL DESIGN

A report of the one-day conference on "Industrial Design and the Engineering Industries" recently organised by the CoID and the Engineering Centre

WHEN the Council of Industrial Design was set up in 1944 as a grant-aided body under the Board of Trade, its terms of reference were "to promote by all practicable means the improvement of design in the products of British industry". Although the C.o.I.D. with its limited resources has hitherto centred its activities around durable consumer goods, it has always wished to be of service to the engineering industries which are one of Britain's most important export trades.

The conference held on November 12 was the first of its kind to be held in Britain, and growing realisation of the importance of the subject was indicated by the fact that no less than sixty-five of the 120 delegates represented top-level management in a wide range of engineering industries. The lively discussion which followed the addresses showed how many firms are taking an active interest in product design in its widest sense, including such things as appearance, safety, cost and ergonomics. Sufficient time was allowed for discussion to enable contributions to be made by over thirty delegates, many of whom were design engineers or design consultants.

The Rt. Hon. Lord Mills, Minister of Power, in his address, "The National Importance of Good Industrial Design", set the tone of the conference by contrasting the purely functional engineering of the early pioneers, who considered that beauty of line played no part in design, with the present-day situation in which out-of-date designs cannot hold their place in a competitive world. Lord Mills considered that the three most important factors are price, reputation and appearance and, if everything else is equal, then it is the appearance of a product which determines sales. The overseas buyer is important to all firms and it is vital that he should be impressed by the appearance of British products.

A point of great interest but on which varying opinions were expressed was the wisdom of engineering firms calling in outside design consultants to assist in the styling of a product. Mr. G. S. C. Lucas described the way in which industrial design is being tackled in the A.E.I. group of companies, which has fifty factories and about 90,000 employees in the British Isles alone. He stressed that the engineering designer already has his full quota of responsibilities in preparing layouts and manufacturing drawings which demand the full display of his knowledge of engineering, factory processes and standards. The appearance designer, however, requires a separate training and experience, and, in addition, must have a natural aptitude for his work. Therefore, the A.E.I. policy is to employ outside consultants for appearance design and to appoint an industrial design sub-committee responsible for seeing that the consultant's advice is reflected in the products of the company. The A.E.I. group are also training drawing-office apprentices in appearance design, not with the object of replacing the outside consultant but to enable them to have a better appreciation of appearance when they eventually become engineering designers.

Mr. Misha Black, in his paper "The Role of the Industrial Designer", pointed out that the circumstances of some companies justify the employment of staff designers instead of calling in outside consultants but, in either case, their services are identical in providing skilled professional advice. The consultant, however, can usually provide a wider experience gained in many industries and may also prove a valuable critic. Mr. Black outlined nine qualifica-

tions which the industrial designer should possess in order to fulfil his proper function in industry. He emphasised that, apart from his technical qualifications in the artistic sense, the industrial designer should have a reasonable understanding of technical potentialities and limitations as well as the ability to sense the changes in world taste. He must also show a spirit of true co-operation with his colleagues, by putting over his ideas clearly and emphatically but getting on with them as a reasonable human being.

Mr. Louis Schuler, managing director of L. Schuler A/G (Germany), emphasised the important part played by the customer. In his paper, "Appearance Design of Power Presses", he explained that not long ago the customer merely asked for a reliable machine of up-to-date technical design, but in recent years the world outlook has changed considerably and the customer now expects the latest technical developments coupled with good appearance. Even in the field of power presses, which are built for purely utilitarian purposes, it has been found impossible to achieve satisfactory sales without due regard to appearance.

Mr. Schuler showed how modern constructional methods greatly assist the appearance designer. In the past, the use of large frames cast in one piece meant that all linkages and controls had to be fitted externally, whereas the use of fabricated box frames made in several pieces now gives the designer greater scope in obtaining a pleasing appearance. Additional advantages of this form of construction are the reduced danger of accidents caused by external mechanisms and improved life of sliding parts and other working surfaces by exclusion of dirt. The demand for good appearance has therefore caused some technical improvements.

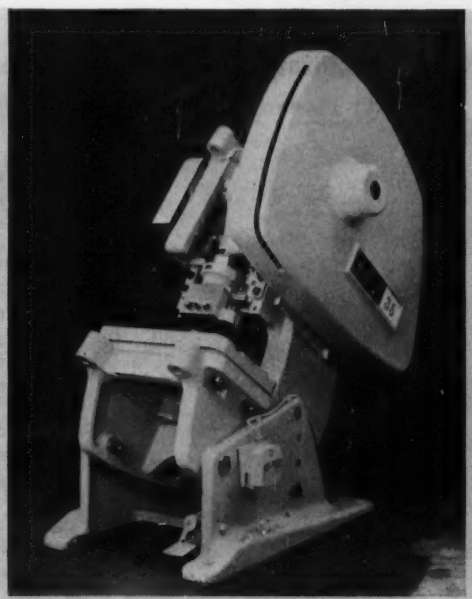
"Industrial Design in Heavy Engineering" was the title of a paper read by Mr. A. Ashley on behalf of Mr. John Anderson, manager of the power press department, Vickers-Armstrong (Engineers) Ltd. He stressed the importance of designers getting out into the field to study competitors' activities and to hear at first hand the criticisms and experiences of salesmen and agents in all parts of the world. Designers were exhorted to remember the service engineer's point of view and to listen to his comments on the many small faults which might be put right with a little thought by the designer.

The training of personnel, which was one of the main objects of discussion, was considered to be of very great importance in making sure that Britain's engineering products were up to date in all aspects. Mr. Ashley pointed out that the system of training employed by many large firms was a technical schooling, followed by a haphazard apprenticeship in the workshops and several years detailing in the drawing office. The training of designers by such methods was a sure way to perpetuate the mistakes of the past. A much broader training was advocated, including an opportunity to follow products through all stages of manufacture, a period with the service engineer and some experience of technical sales.

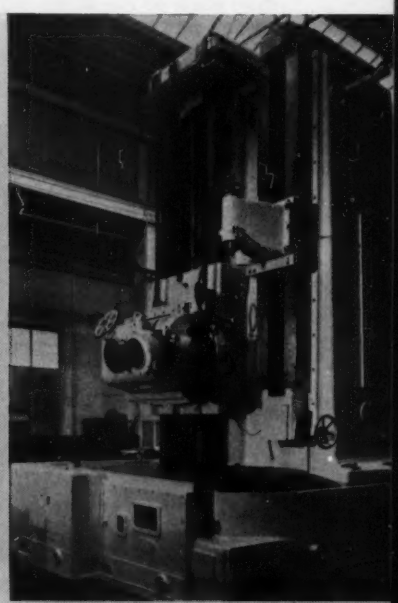
Some British companies have been fully conscious of the importance of industrial design for many years, and W. & T. Avery Ltd. have employed design consultants for twenty-five years. They have taken this action because they are certain it is not only in the national interest, but that good design leads to full order books and a prosperous business. Dr. E. W. Seward, technical manager of this company, remarked that in cases where industrial designers have been tried and found to be impracticable, this is an admission of failure to use them properly; many speakers thought it the responsibility of management to see that the design team runs smoothly with a spirit of co-operation between technical and appearance designers. Particularly on consumer products such as washing machines, it is very important to call in the industrial designer at a very early stage so that the good appearance can be built into the product instead of being added as an afterthought. In Dr. Seward's company the design policy originates at board level and is the direct concern of the chief executive. The design policy is implemented by a design council on which all relevant interests such as sales, financial, technical, planning and production are represented. Dr. Seward showed how the use of perspective drawings and wooden models greatly helps the decisions on new designs, but he emphasised the importance of models being complete in every detail, including surface texture and colour.

Differences of opinion on many points came to light during the discussion, and it is obvious that many difficulties will arise in deciding how a particular industry or firm can best tackle its design problems. It is to be hoped that this conference will stimulate engineering firms to review their design programmes and impart a sense of urgency to those already active in the pursuit of better designs. It must, however, be judged a success if it only sets the right people thinking on the right lines by paving the way for further meetings where designers, engineers and management can exchange ideas on a subject of domestic and national importance.

Dr. E. W. Seward, technical manager, W. & T. Avery Ltd., emphasises the attention to detail that his company feels is necessary in wooden models



A Bliss open-fronted inclinable power press on which great attention has been given to detail. The styling of the glass-fibre flywheel casing is particularly



David Brown vertical turbine pinion hobbing machine. Less consciously styled than many shown at the Birmingham display, the detailing of the tailstock and the work

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

Gear Boxes and Gear Changing Eliminated in Dutch Car

THE Variomatic transmission system, a major feature of the Dutch D.A.F. car, by using two infinitely variable V-belt drives, makes possible a fully-automatic reduction system offering unique advantages from the standpoint of both driver and manufacturer. Speed changing is automatic and gears are largely eliminated.

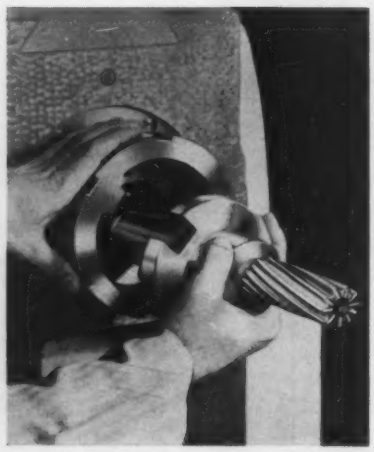
Drive from the engine is taken via a centrifugal clutch in the flywheel housing through the transmission shaft to the power divider. Here three bevel gears enable the driving power from the pinion on the transmission shaft to be transferred via a dog-clutch to either the left- or right-hand bevel gear on the shaft carrying the front pulleys, or to a neutral position. Operation of the dog-clutch is by a short lever located next to the driver's seat.

When the centrifugal clutch has operated and the vehicle is in motion, centrifugal weights in the front pulleys increase the axial thrust on the sliding pulley halves and cause the V-belts to run on larger diameters in the front pulleys. The pull exerted by the belts is sufficient to overcome the force of springs mounted in the rear pulleys to keep the belt under tension. By merely pressing the accelerator pedal, the gear ratio change takes place from bottom gear to overdrive. The overall ratio can be varied from 20:1 to 4·4:1. In addition to the use of centrifugal force and tractive power in the V-belt, engine vacuum is also employed to select the correct ratio. The front pulley assemblies, in addition to being provided with centrifugal weights, also have vacuum cylinders in order to provide an automatic overdrive in all ratios. The amount of vacuum power available depends on engine speed. Normally this vacuum is arrested by a valve when the accelerator pedal is fully released. It is possible, however, to admit this vacuum in the opposite direction, by means of a knob on the dashboard, and so bring about a sharp changing down of the Variomatic, regardless of the car's own speed. This is generally only employed when descending long, steep gradients.

In addition to the elimination of a conventional differential gear which this transmission system makes possible, the manufacturers point out that it also provides a rear drive having all the advantages of such a gear with one additional virtue. If a car fitted with a normal differential gear encounters conditions where one rear wheel rotates freely, as might occur in icy conditions, all tractive effort is lost on the other rear wheel. With the Variomatic, however, drive to each rear wheel is by separate V-belt, and although deceleration of one rear wheel and acceleration of the other occurs at corners, as with a differential, the drives being separate, slipping and spinning of one rear wheel does not affect traction from the other.

The L-shaped welded members to which the half-shafts are assembled swing about an axis which coincides with the tight side of the V-belts, so that the latter is not affected by the spring movement of the rear wheel.

Device Facilitates Milling Arbor Removal



THE Arbor-Loc, a recent Cincinnati development, eliminates the use of draw bolts for retaining milling arbors. The fitting of arbors, collet adaptors, chucks, etc., is now made a simple one-man job.

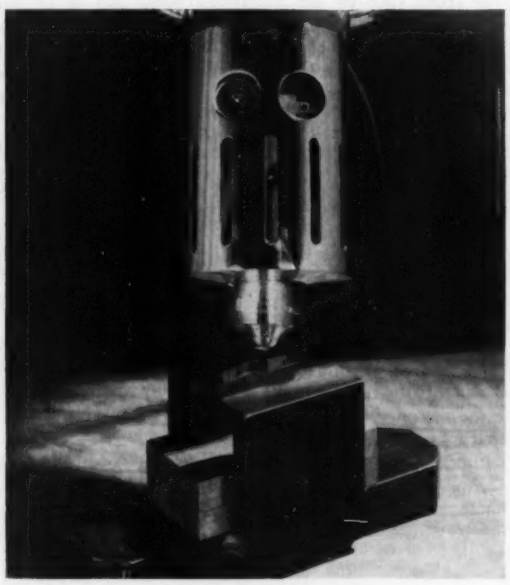
Already a feature of new Cincinnati milling machines, the device can be fitted to existing machines by turning a groove in the spindle nose, using a special gauge provided for the purpose.

The device consists of two internally-grooved halves which are held on the outside of the spindle nose by a garter spring and provide, when assembled, a screw thread on to which a large nut is fitted. The arbor flange is held by two inwardly projecting lugs.

New Assembly Techniques Possible with Portable Injection-moulding Machine

THE A.P.M., a small hand-operated plastics moulding machine, makes possible the moulding *in situ* of a whole range of articles in thermoplastic materials. Until recently, thermoplastic components were produced in costly dies, designed to fit particular makes of injection-moulding machine. The production of such dies is only justified when the production of long runs is envisaged. Although small try-out presses are sometimes found, their use is generally confined to the workshop or laboratory. With the A.P.M., however, the press is taken to the job, and seals, insulators, cable junctions and even rivets can be moulded in this way. It would appear also to make possible a series of new assembly techniques, e.g., using injected plastics for the keying of gears to shafts.

The A.P.M., bearing a resemblance to a portable hand drill, measures 16 in. × 6 in. wide and weighs 12 lb. A narrow vertical cylinder, provided with a swing latch door for the entry of raw material in granular form, forms the main body of the machine. The lower half of the cylinder is surrounded with an electrical heating coil which may be operated from the mains or from a 24-volt battery,



temperature being controlled by an energy regulator and indicated by a rotary thermometer. The plunger barrel carries a thread on which a nut revolves driven by the handle through bevel gears. The plunger enters the cylinder from the top and forces the plastics through the heated section and out of the nozzle into the mould. A volume of granular material always remains as a buffer between plunger and plastics. The cylinder is self-cleaning and material can be left in it for long periods. The swing latch type of filler cover enables the machine to be used in an upright or inverted position.

All types of thermoplastic materials can be moulded, although in some cases, as with nylon, a different type of cylinder must be used. Capacity for one shot is one ounce. The cost of a simple die for a run of 10,000 mouldings would be around £15. A cheaper mould can be made from low-melting-point alloys, in special plasters and rubber.

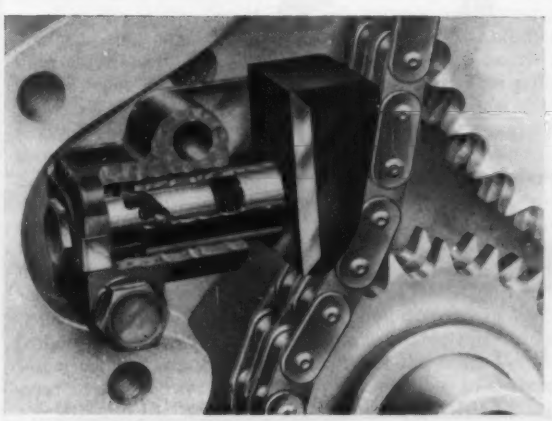
Chain Tensioner for Camshaft Drives

THE Renold SCD auto-adjuster is a device that is designed for the correct maintenance of chain tension on camshaft drives.

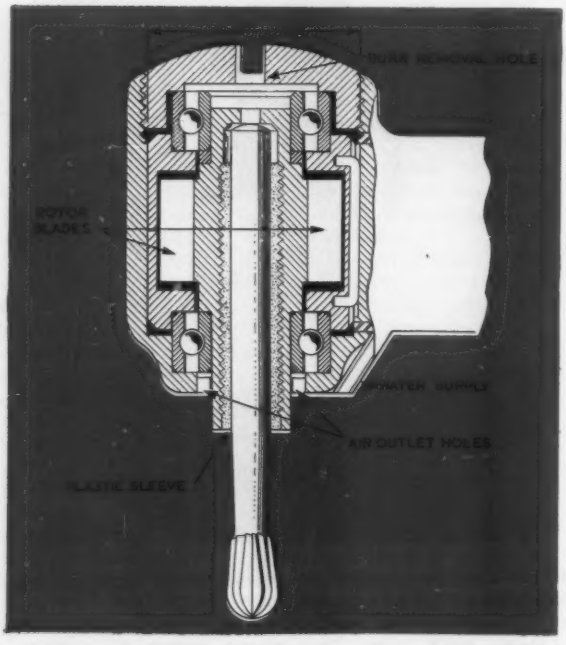
Basically, it is a cylinder housing a rubber-headed plunger which contacts the chain on the non-driving strand and is pushed against the chain (with the desired degree of loading for correct tension) by spring and hydraulic pressure.

The device incorporates a ratchet non-return mechanism which is an essential basic feature of a correctly-designed adjuster. This allows sufficient retraction of the rubber slipper-head to compensate for variation of centres due to heat expansion, but prevents undue backward movement. This amount of retraction is maintained unvaried throughout the life of the chain; the slipper takes up excessive slack which develops, but always under ratchet control.

The device is pressure oil-fed from the slipper-head.



Miniature Dental Air Turbine revolves at 250,000 r.p.m.



A SIMPLE six-bladed rotor, mounted in two miniature precision stainless-steel ball bearings, forms the driving unit of the Borden Airotor, a new ultra high-speed dental drill made by Amalgamated Dental Engineering Industries Ltd.

A sectional view of the rotor, the outside diameter of which is only ¼ in., is shown above. The turbine shaft is hollow and threaded and into its forward end a plastics sleeve is fitted which acts as a friction grip chuck to hold the cutting tools. A central hole in the back cap of the handpiece head allows a tool to be inserted right through the turbine to remove the cutting tools.

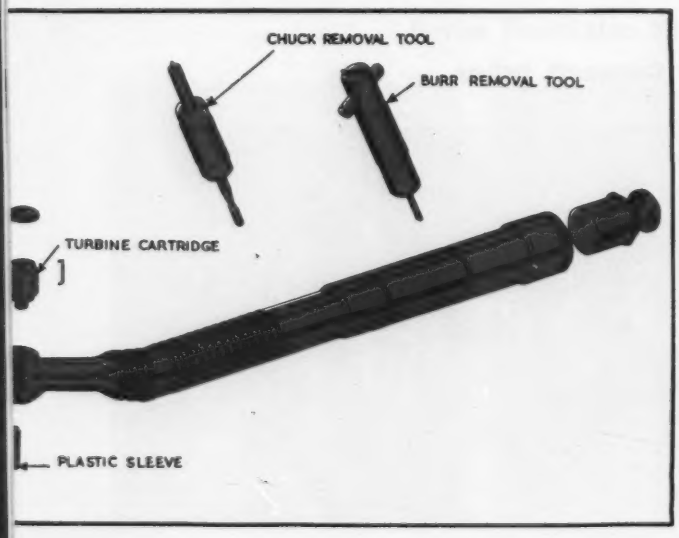
Air supply to the turbine, which can be pressure-regulated by a knob on the control box from 10-30 p.s.i., is provided by an air compressor of the vane or piston type and controlled by a foot-operated solenoid valve. Air from the compressor reservoir passes through a Norgren filter and moisture extractor which, using a sintered metal filter element, removes all particles down to 10 microns dia. A moisture exhaust valve at the bottom of the filter allows moisture to be blown off periodically. From the filter the air passes to the air regulator and thence to a solenoid valve and a Norgren oil mist lubricator and then on to the handpiece by a plastics tube. The oil used is a pure, specially-filtered olive oil with anti-oxidising additives. Mineral oils are unsuitable, as they cannot be absorbed by the lung tissue of the operator.

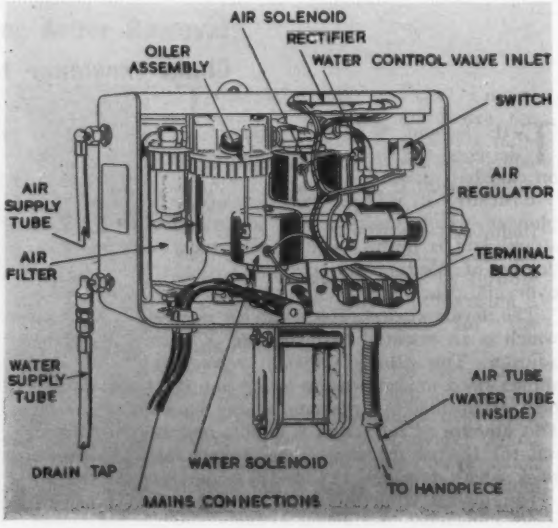
Exhaust air from the turbine passes through three holes in the front face of the handpiece head and in so doing provides a sheath of cooling air around the cutting tool. It is also exhausted backwards through two holes in the back of the handpiece head. The two exhaust systems keep the bearings lubricated and more or less "floating on air". The remainder of the air is exhausted down the handle of the handpiece and escapes at the connector between the supply tubing and the handpiece.

Water is provided for cooling the cutting site. This is heated a little to an equable temperature for the patient. It is carried to a fourth small hole in the front face of the handpiece head through a second tube running inside the air supply tube. When the supply is opened a fine jet of water is injected into the air stream surrounding the cutting tool.

The advantage of the air turbine-powered drill, for the patient, is that drilling is painless, as there is no vibration and practically no generation of heat. From the dentist's standpoint, only a very light touch is necessary and cavity preparation is speeded up.

Although the Airotor was developed for dental use, experiments carried out by the manufacturers suggest that it has a number of possible applications in industry, particularly where very hard materials, such as ceramics, must be drilled.





RECENT PROGRESS IN NON-DESTRUCTIVE TESTING

Inspection requirements of modern engineering have led to increasing interest in the use of specialised techniques for examination of materials and components. This article reviews some of the methods being adopted on both sides of the Atlantic

by A. C. RANKIN, A.I.M.*

FUTURE engineering development is governed to a considerable extent by the materials of construction which become available to designers. It is well recognised, therefore, that metallurgists have an important part to play in engineering development, particularly in such fields as aviation and nuclear engineering. Considering the many new and improved alloys which have become available within recent years, it is evident that the metallurgist is satisfactorily fulfilling his responsibilities.

The engineering designer assumes that the properties of the materials which he uses conform to some written specification. In general, the guarantee that the actual batch of material which is used for production purposes is, in fact, satisfactory is based upon the premise that measurements taken upon carefully chosen samples are representative of the material as a whole. While for most general engineering purposes this procedure has proved very satisfactory in the past, modern specialised designs of critically-stressed components cannot always rely upon it. For this reason, there has been a trend towards an extension of the use of non-destructive tests to supplement information obtained by sampling. At present, most non-destructive tests are concerned with the detection of defects in the material, since the positions at which defects such as cracks and porosity occur are notoriously unpredictable. However, there is also a growing realisation that in many applications there is also a need for specialised non-destructive tests which will ensure the constancy of mechanical properties throughout the material as a whole.

The idea of non-destructive testing is certainly not a new one. Examples such as visual examination, proof loading, and even weighing of materials, demonstrate that the use of non-destructive methods extends well back into the history of engineering. Nevertheless, it is largely due to a rapid growth in the use of specialised physical techniques, such as radiographic, magnetic, electrical and ultrasonic testing, that the general phrase "non-destructive testing" has now become an important one in our engineering language. There can certainly be no doubt that the marked increase in the use of these newer techniques has had a considerable impact upon the thinking of personnel concerned with inspection. These methods have come into widespread use as a direct consequence of the inspection needs of modern engineering, and in many applications they are considered indispensable. On less critical applications, unfortunately, problems have arisen in the application of these tests, mainly because of their high sensitivity, which reveals imperfections of a relatively small nature. The information obtained is not always easy to interpret in terms of the serviceability of the component in question, particularly when the designer is aware that before these inspection methods became available, these same small defects must have been present.

Nevertheless, the development of non-destructive testing is a matter of primary importance in the design and manufacture of aircraft missiles, high-speed rotating electrical assemblies and similar engineering products. It is also of economic interest to industry, since by eliminating defective material at an early stage of production before many hours of machining have been wasted, decreases in the cost of production can be secured. Another field where non-destructive testing has proved most valuable is in the early detection of defects arising in service, such as the detection of fatigue cracks in the axles of rolling-stock upon railroads. Indeed, non-destructive testing has quietly and steadily improved the safety of the world's railways, automobiles, ships, mines and building structures, by the anticipation of failure prior to the actual occurrence of an accident. If, in the design of many components, attention was paid to securing conditions which would enable non-destructive testing techniques to be applied easily in service, even greater safety could be secured. This policy is being followed successfully, for example, by one of the leading aircraft companies in the U.S.A. At the design stage of components, a non-destructive testing expert is called in in order to discuss where certain changes of design would permit more satisfactory non-destructive testing during the service life of the aircraft. Without detracting from the engineering performance of components, changes of shape can be made which makes a vast difference to the service inspector's task.

Despite the accepted success of non-destructive testing techniques, it is quite clear that the available methods are imperfect and inadequate for many of the tasks likely to arise in the future. It is not always possible to delineate the size and the nature of defects accurately for the pur-

* *Head of application research group, non-destructive testing laboratory, Kelvin & Hughes Ltd.*

An automatic method of ultrasonic testing of rotor forgings for internal faults is being investigated by G.E.C. using a Solus-Schall flaw detector in conjunction with a monitor. By the provision of electronic apparatus, to mark the position of any fault in the rotor automatically, it is hoped that constant attention by an operator will be eliminated.

pose of interpretation. In general, as yet, it is not possible to predict accurately "point to point" variations in the mechanical properties of the materials upon which design is based. Upon the results of non-destructive tests, nevertheless, decisions regarding the acceptability of material have to be taken, and clearly these decisions sometimes have to be arbitrary. The information given by most non-destructive tests is qualitative, and, relying mainly upon past engineering experience, a decision has to be made, which in the case of advanced designs often involves extrapolation of experience. With many such extrapolations, risks are involved. This leads to a tendency on the part of inspectors to reject, rather than to accept, defects considered borderline.

Significance of Defects

This particular aspect of the subject, "the significance of defects", is surrounded by a great deal of controversy. Unfortunately, the resolution of this controversy is a most complex matter and reaches far beyond the interpretation of a non-destructive test. There cannot be a simple formula which will solve the issue, since there are, in fact, as many issues as there are sets of conditions, and the same defect can behave quite differently for example, with different magnitudes and types of mechanical loading, degree of internal stress, operating temperatures, surrounding atmospheric conditions, as well as with the metallurgical properties of the material in which the defect is situated. Nevertheless, there is an obvious goal at which non-destructive testing must aim—the accurate description of defects in quantitative terms, since unless this goal is reached, the application of any experiences or theories dealing with the significance of defects cannot ever become satisfactory.

Although the inadequacies of the available non-destructive testing methods can be clearly recognised, wide acceptance by industry has been achieved. Until a few years ago, most of the non-destructive testing techniques available involved rather slow manual processes of examination. Accordingly, there has been a great deal of effort put into the development of semi-automatic and automatic non-destructive tests. This has been particularly true in the eddy current and ultrasonic testing fields which, from the practical point of view, are both more readily automated than other classical methods, such as film radiography and magnetic particle testing.

The country in which most publicity has been given to practical progress in the application of non-destructive testing techniques is the U.S.A. Towards the end of last year a European Productivity Agency Mission, of which the author was privileged to be a member, made a tour of the U.S.A. with the express purpose of studying the progress which had been made. The official report of this mission will be published shortly, and it is not intended here to anticipate its final conclusions. However, in the personal opinion of the present author, technical developments in the U.S.A. are no further advanced than they are in Europe, and no new techniques have been noted of which European technologists are unaware. The impression that greater progress has been made arises largely from the large volume of literature concerning practical application which has been published by the American Society for Non-Destructive Testing. There is no doubt that increased encouragement to British workers in the field should be given, since it is only by the publication of practical experiences in the adaptation of non-destructive techniques for different purposes that experiences can be made available for more general use.

The technical performance of almost all of the commonly used non-destructive testing techniques has been improving gradually in recent years, but except in a few isolated instances there have been no major developments in fundamental technique which have given rise to important new practical methods of testing.

In the field of X-radiography, the introduction of high-voltage sources, such as linear accelerators and betatrons, can be regarded as an important development. Experience shows that these units provide improved radiographs of relatively thick sections of material. For example, a 6-Mev linear accelerator is quoted by American authorities as being capable of handling steel thicknesses of from 2-10 in. upon a routine basis. Definition is substantially improved, and with this unit a geometrical unsharpness of 0·024 in. ($\frac{D}{T} = 10$) has been claimed. It permits a greater latitude in the thickness ranges which can be handled on one shot up to about $3\frac{1}{2}$ in. Comparing this to the 1-megavolt resonant transformer X-ray generator—here the thickness range is $\frac{1}{2}$-6 in.—the geometrical unsharpness is about 0·036 in. at the same $\frac{D}{T}$ value and the thickness latitude in steel is approximately $1\frac{1}{4}$ in. Also, of course, penetrameter sensitivity is increased, and it is common to obtain a value of one per cent. Not only are lower exposure times possible, but also, in many cases, there is a greater simplicity of procedure because of the increased latitude of thickness variation permissible. Another interesting advantage which has been noted is the possibility of panoramic radiography using a reflected beam technique, which permits, for example, the simultaneous exposure of a considerable arc of a circumferential weld.

An interesting feature of recent investigational work has been the increased realisation that the sensitivity of radiography to the detection of fine cracks is not completely adequate. Fortunately, in this respect, ultrasonic techniques are complementary in their performance, and the problem is not so serious as it otherwise would be, particularly in the welding field.

Obviously, these high-voltage units are extremely expensive, and their installation cannot be justified by many smaller factories. It is not only the specific cost of purchasing and of running the apparatus, but also the very considerable protection arrangements which become necessary when dealing with the radiation problem. For this reason, it seems self-evident that the use of very high-energy X-ray generators is likely to be limited to the most critical types of application, and that there is a good case for testing arrangements based upon industrial co-operation. Arrangements of this type have been proposed, particularly for some of the smaller countries in Europe, within, for example, the Benelux countries.

The ready availability of artificial radio-active sources, such as cobalt 60, iridium 192 and thulium 170, has led to a very considerable expansion of the use of the gamma-ray method, particularly in such applications as the inspection of welded pipelines. This is true both in the U.S.A. and Europe. Typical of practice in the U.S.A. is the trend towards rather large ^{60}Co sources up to 1,000 curies strength for the radiography of heavy steel castings. However, in pipeline work in the U.S.A. it has been found that since most wall thicknesses lie between 0·2-0·5 in. in thickness, X-ray techniques with portable units are still preferred in many cases, because of the better contrast which can be obtained. For most pipeline cases where gamma-ray sources are chosen, iridium 192 with source strengths of between 10 and 20 curies is employed. For aluminium and magnesium sections, thulium 170 and cerium 144 sources are being used more widely. Very good equipment for the safe handling of gamma-ray sources is now available both in Europe and the U.S.A.

In the U.S.A. useful evaluation work is being carried out upon xeroradiography and fluoroscopy at Ohio State University by Professor R. C. McMaster. Demonstrations of the relatively new Lumicon method of fluoroscopy, which uses a closed-loop high-resolution television system to transfer observations to a safe site, and to achieve image intensification, showed that upon aluminium alloys between ¼-2½ in. in thickness, with a 220-kV X-ray set, a penetrameter sensitivity of 2 per cent can be achieved. The xeroradiographic method is finding increased industrial application in the U.S.A., particularly upon light alloy castings.

Magnetic-particle Testing

Considering next the well-known magnetic particle testing techniques, it is true to say that there has been no major development in this field. Over the last ten years continuous improvements have been made in the visibility of fluorescent magnetic particle inks, and quite recently there has been introduced a new magnetic testing fluid, in which the particles are suspended in water rather than in paraffin. This leads to lower costs in testing. It also has considerable advantages in terms of maintaining cleanliness of components, and is a feature which has been welcomed in industrial practice where cleanliness must be maintained. Although there has been quite a considerable activity in the introduction of faster methods of handling materials during magnetic particle testing, there has not, as yet, been developed a practical fully-automatic magnetic testing technique. The use of human operators to locate flaws visually is still preferred, and in the radiographic and magnetic test one has to depend entirely upon the skill and experience of the inspector.

Probably the techniques which have made the greatest

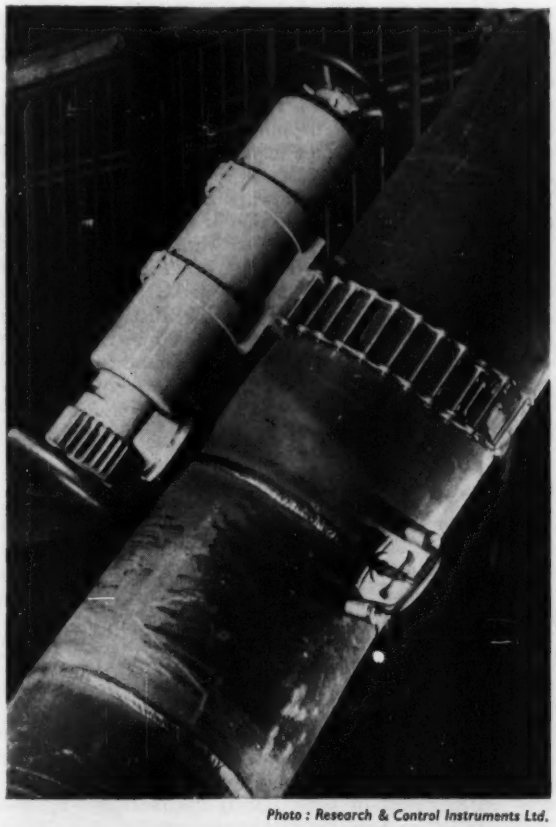


Photo : Research & Control Instruments Ltd.

Macrotank D X-ray unit in position for pipe weld radiography (double-wall technique).

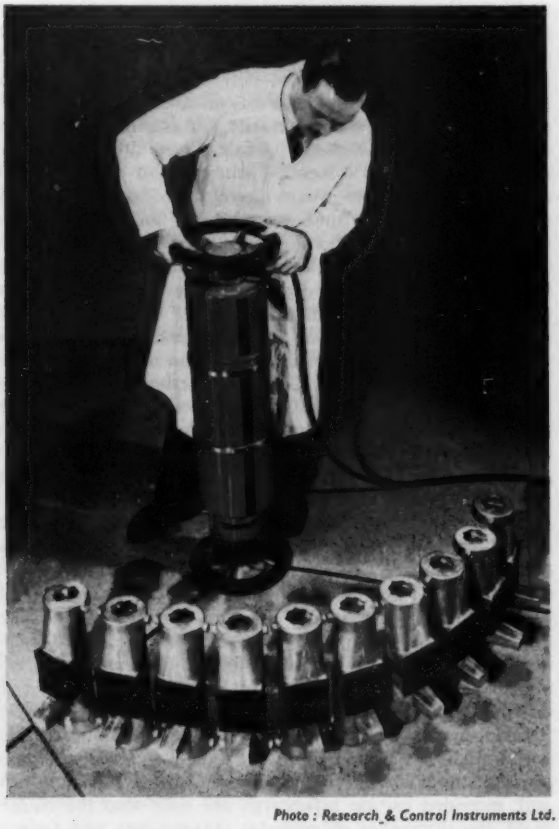
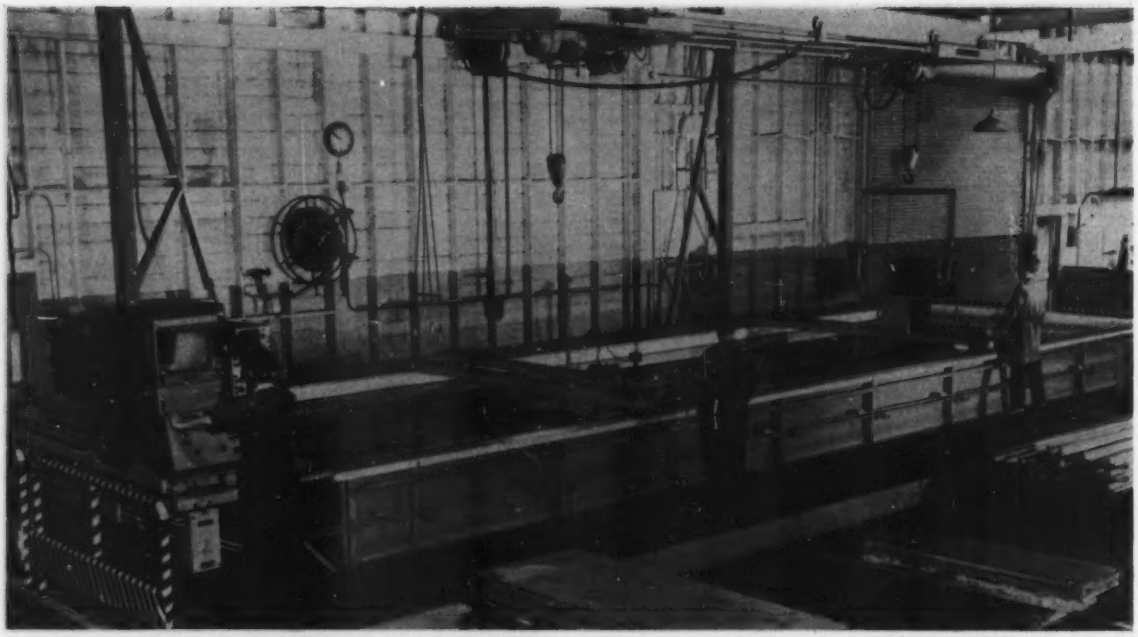


Photo : Research & Control Instruments Ltd.

Positioning for semi-panoramic inspection of castings with an X-ray unit.



Automatic plate scanner (ultrasonic) used for testing light alloy plate by the Douglas Aircraft Co.

practical progress within recent years are those based on ultrasonic wave propagation. From a small beginning some fourteen years ago, they have come into widespread use, and at the present time there are at least three thousand ultrasonic flaw-detection units in use throughout the world. A fascinating characteristic of ultrasonic flaw detection is the extremely wide range of application. The detection of discontinuities in metals and alloys is, of course, the application most well known, but very many examples of application outside the field of metallurgy exist. Ultrasonics are being used satisfactorily, for example, upon such diverse materials as glass, porcelain and other ceramics, compressed carbon, wood, plastics and resin-bonded cloths. Within recent years there have been no major developments in the fundamental techniques of ultrasonic testing, although considerable refinements have been introduced. In the pulse echo type of instrument there have been progressive improvements in the characteristics of equipment, particularly the transducers. The shortening of pulse lengths has increased the resolution of echoes from defects closely situated to each other and to the boundaries of the materials tested. The introduction of immersion techniques, and of gap techniques, where water is used for the coupling of the acoustic transducer to the material under test, has to a considerable extent replaced the oil couplant originally regarded as essential. This has been one of the main factors which has permitted the introduction of speedy testing methods, and, indeed, the automatic testing equipment now available relies upon the constancy of energy transfer obtained by these new coupling techniques. Having now removed this undesirable variation of energy transfer, the use of electronic gating circuits with automatic flaw alarms has become practical, and such devices have been developed by instrument manufacturers and are now in commercial use. In many instances it is now possible to obtain reliable results when moving a transducer over surfaces at speeds of several hundred feet per minute. This had led to the much wider application of ultrasonic testing for production inspection purposes and, provided certain safeguards are built into the equipment, the difficulties of operator inexperience and fatigue can be minimised.

Strictly speaking, there are still serious limitations in the application of ultrasonic flaw detection, mainly in interpreting what significance to apply to the amplitudes of the echoes which arise from discontinuities within materials. In the case of the aircraft industry, working upon light alloy materials, much work has been done in attempting to correlate defect echo amplitude to defect size by comparing the echoes obtained with echoes from artificial targets, such as flat-bottomed holes. In specific cases, some degree of correlation can be obtained, but in others one often finds some anomalies. This degree of unpredictability can be ascribed largely to differences in the shape of the defects, to differences in the material of which the defect is composed, and in some cases to the thickness of defects. This means that it is not always safe to assume that a defect will give complete reflection of the ultrasonic energy which is incident upon it. Thus, while some correlation may be expected where defects are of a constant type and orientation (for example, when produced by rolling), the same assumptions cannot be applied satisfactorily when the shape and orientation of the defect may vary within wide limits. There is no doubt that some more fundamental method of estimating flaw size must be developed, and in this respect measurement of reflection amplitude is unlikely to be a satisfactory approach.

Ultrasonic Resonance

One of the techniques of non-destructive testing, which is quantitative, is the measurement of thickness by ultrasonic resonance and echo techniques. Recently in the U.S.A. automatic thickness-recording devices have been introduced, and accuracies of ½-1 per cent are claimed. The main limitation on this technique is associated with acoustic coupling at high speeds, but for "point to point" testing purposes it represents a considerable advancement in the art.

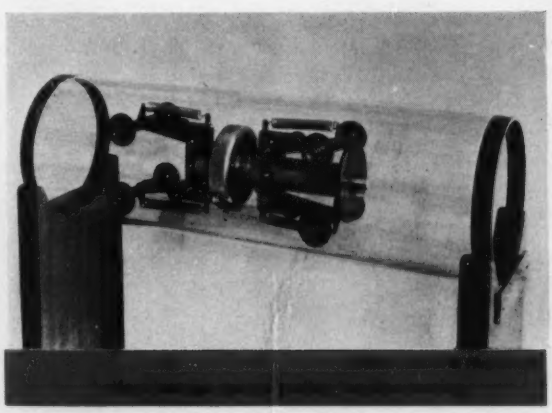
Useful applications of ultrasonic thickness measurement noted during discussions in the U.S.A. were the periodic measurement of ship hull thickness during service, thickness measurement of sheet during chemical milling and measurement of bore eccentricity in metal tubing. While these applications are known and practised in Europe, the scale of operations is far more limited.

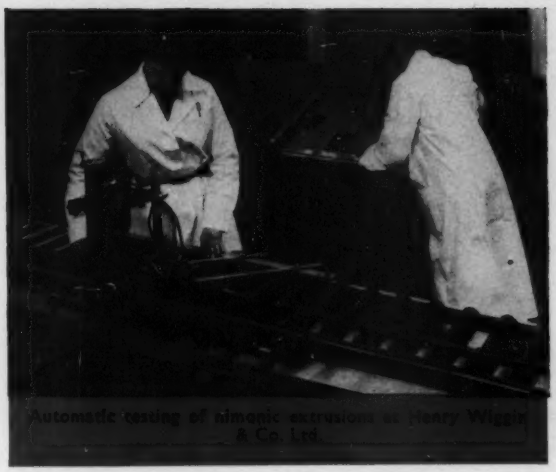
Other very promising methods of non-destructive testing are those based upon the use of eddy currents and magnetic fields. These are not new techniques, since the basic principles have been known for some fifty years. It is only, however, during the past ten years that really practical methods have been developed, particularly by Förster in Germany. The most attractive feature of these methods lies in their ability to detect changes in material, other than those due to discontinuities, which can affect the permeability or electrical resistivity of the material. Serious problems arise, of course, in the separation of the important from the unimportant variables. For example, changes in resistivity may arise both from alterations in chemical composition and metallurgical structure. At the moment trial-and-error methods are used to determine the optimum conditions of test. However, as experience grows it should certainly be possible to apply magnetic and electrical tests more widely for purposes other than for the detection of defects such as cracks. To a considerable extent this depends upon the interpretation of changes in resistivity, permeability, etc., in terms of changes in metallurgical structure, as pointed out by Dr. E. G. Stanford.

It is interesting that in the field of nuclear reactor technology the main criterion for the satisfactory service of components is not always that of resistance to imposed stresses. One of the very important requirements is the inspection of vessels and pipes and other components for the leakage of gases and liquids. This need has led to the development of highly-sensitive leak-detection techniques. The use of halide leak tests and mass-spectrometry has been considerably extended both in Britain and the U.S.A. The sensitivity achieved can be fantastically high. One figure quoted by D. W. Ballard, for example, is one-c.c. leakage in 500 years.

Bearing in mind our comments upon the need for non-destructive tests to measure changes in some physical property of alloys, thereby giving an indication of changes in mechanical and other significant properties, it seems likely that fundamentally new principles will have to be used. One possibility is nuclear magnetic resonance spectrometry. The techniques developed are sensitive to changes of structure at an atomic level, and is the sort of technique which may well prove of increasing value in the future. Ballard, referring to the work done in the Sandia Corporation by Linde, discusses how it is being used to measure the degree of curing in plastics, and also indicates that it shows possibility as a method of detecting nuclear radiation damage to atomic structures a long time before any of the physical properties measured by alternative techniques indicate that changes are occurring.

These few examples show the general way in which non-destructive testing is moving. Much of the difficulty arises, looking at the future possibilities, from the failure of these





Automatic testing of nimonic extrusions at Henry Wiggin & Co. Ltd.

methods to yield information which is both meaningful and quantitative. Most research workers in the field are very aware that it is necessary to modify available techniques in such a way that quantitative information is obtained, but there is the initial snag at the present time that it is not always clear what physical measurements will be of real value. Progress is being made along several different lines. For example, in the field of radiography, the use of radiation-intensity measurement devices to scan the materials is one possibility which has interested many investigators including Hinsley, in this country, and in suitable cases the method certainly shows considerable promise. Again, echo amplitude data in flaw detection, although not as yet regarded as satisfactory, has been used under suitable conditions to gain some assessment of the over-all quality of materials.

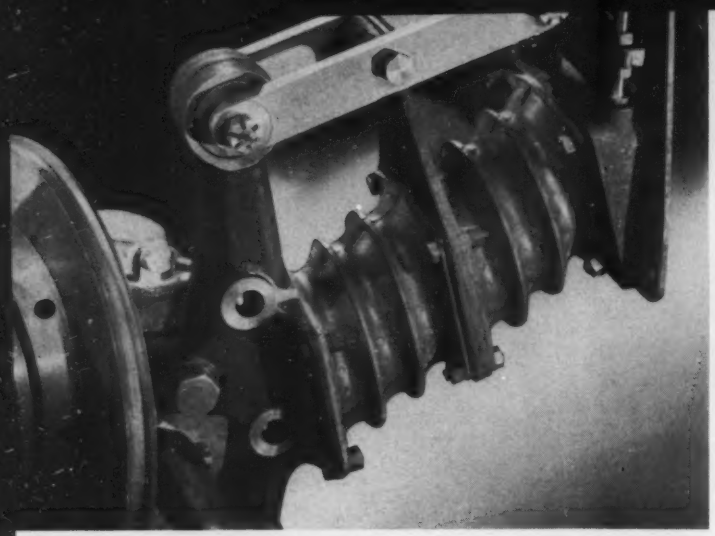
A really important requirement in the future will be to use non-destructive testing as a means of quality control in the metallurgical and engineering industries as automation gradually takes place. One point of view expressed by Dr. E. G. Stanford during the European Productivity Agency Mission to the U.S.A. is that to a very considerable extent the progress of automation is dependent upon the development of improved non-destructive tests. This is a measure of the importance of non-destructive testing to the future of production engineering and metallurgy.

As has already been stated, much work remains to be done in non-destructive testing to achieve the transition from art to science which is essential. This work will have to be done at all levels, upon fundamental principles, upon instrumentation, and upon application engineering. Some of the problems to be dealt with are fascinating, and represent a challenge to physicists, engineers and metallurgists alike.

A measure of the increasing interest in the subject is given by the number of postgraduate courses now being organised by the universities and colleges, and by the number of national and international conferences. There is a British National Committee for Non-Destructive Testing on which all of the main professional societies are represented; and there are groups such as the Society of Non-Destructive Examination, the Non-Destructive Testing Society of Great Britain and the Non-Destructive Testing Group of the Institute of Physics, which are specifically interested in the development of the art.

Whatever one chooses to think about non-destructive testing, one thing is certain: it is impossible to do without it in this modern age.

Stanford, E. G. *Bulletin of the Institute of Physics* (1956) **7**, 44.
Ballard, D. W. *Journal of the Society for Non-Destructive Testing*, **XV**, 4, July, August, 1957.



All-rubber Metalastik front suspension for a bus.

RUBBER AS AN ENGINEERING MATERIAL

An introduction to the use of rubber for springs, mountings and shock absorbers, with examples of the kind of calculations involved

by S. W. MARSH, M.I.Lo.E.*

NEW uses are constantly being found for both natural and synthetic rubber in mechanical, civil, electrical, marine and railway engineering. With their development, the designer has been faced with a new range of problems.

For engineering applications, the use of rubber in tension can be disregarded: only its applications in compression or shear—or a combination of both—need be examined. Compression will be considered first.

If a design engineer has decided to use rubber for a particular application, the first consideration is the space needed to house the unit. To determine this, the following particulars are required:

(a) Maximum load to be applied.
(b) Whether there is a static load only or a combination of static and dynamic.
(c) If dynamic, the frequency of load application.

There are several schools of thought as to the permissible stress to which rubber should be subjected. In the writer's opinion, this entirely depends on application. For example, if a unit is to carry a reasonable static load and then be called upon to withstand a fairly severe dynamic load at frequent intervals, the allowable static stress should be much less than in the case of static loading plus infrequent dynamic applications. There is also the question of percentage deflection, as this possibly has much more bearing on the life of the unit than surface stress. Rubber is quite capable of withstanding loads of up to one ton per square inch or even more, but this is not recommended for engineering uses. It is necessary, therefore, to consider each case on its merits; a hard and fast rule cannot be set, but it can be generally accepted that a compressive stress of up to 500-600 p.s.i. is the normal figure for engineering applications. In order to use the empirical formula in design work, certain factors must be known and some explanation would help here.

The formula for determining the deflection of rubber in compression is:

$$d = \frac{F.T^2}{A.E.Q}$$

where

d = deflection in in.; T = thickness of rubber in in.;
F = force applied in lb.; Q = shape factor;
A = cross-sectional area in in.^{2}; E = modulus C.

Modulus, of course, refers to Young's Modulus of Elasticity and not the "modulus" term often used by the rubber chemist. Rubber qualities are usually specified in terms of hardness value. There are a number of different hardness measuring instruments in use, but the most common in this country are the Shore durometer and the B.S.I. hardness tester. The Shore durometer is probably the most widely used and the following gives average modulus values corresponding with hardness figures;

Shore Durometer	*Modulus (C)*	*Modulus (shear)*
38/42 deg.	270/ 280 p.s.i.	80/ 85 p.s.i.
50/54 deg.	365/ 385 p.s.i.	105/115 p.s.i.
58/63 deg.	540/ 560 p.s.i.	125/140 p.s.i.
67/71 deg.	740/ 760 p.s.i.	185/195 p.s.i.
77/81 deg.	1,000/1,300 p.s.i.	270/290 p.s.i.

The shape factor use is dependent on just what it says. In the case of a rectangular unit it is the length of the shortest side, in the case of a circular unit its diameter, and in the case of a circular unit with a hole in the centre, the outside diameter minus the inside diameter. As is generally known, rubber in compression has a rising rate load deflection curve and it can be generally accepted that it has no yield point as for metals. For approximately 25 per cent of deflection from free height, however, the load deflection characteristics are linear and in the majority of cases such percentage deflection should not be exceeded.

It should also be appreciated that rubber volume does not decrease with compression but merely displaces, and, therefore, excessive deflection can cause extreme side bulging which in time would cause wall cracking due to surface stresses. Many cases could be mentioned to show the use of rubber compression blocks. A good example to illustrate by calculations is the recent application of rubber to replace the conventional rocker and roller for bridge bearings.

Before passing on to this, it should be mentioned that the development of methods for the bonding of rubber to metals has opened up entirely new fields for rubber. In the past, rubber sandwiches were often used for the mounting of a machine to a structure by bolting direct through the rubber. This meant that the rubber was only doing a partial job, as high-frequency vibrations could be transmitted from the machine to the structure through the

* *Technical manager, André Rubber Co. Ltd.*

bolt, there being complete metal-to-metal contact. This can now be entirely overcome by a bearing unit in which rubber is bonded to metal units and mounted in such a way as to eliminate completely metal-to-metal contact. These points are illustrated in Fig. 1.

It is important, in such a case to ensure that the rubber in shear is capable of looking after the maximum horizontal forces, if any, which may occur.

For the bridge units it was necessary not only to design a bearing that had a reasonable deflection in compression, but also to reduce the shear forces as much as possible in order to reduce stress on the piers to a minimum.

Fig. 2(a) shows a rubber block 24 in. × 16 in. × 4 in. thick. Let us first assume that such a block is made of solid rubber having a shore hardness of 67-71 deg. and a modulus of 750 compression and 190 shear.

$T = 4 \quad Q = 16 \quad \text{Area} = 384 \text{ in.}^2$

Assume maximum load of 100 tons,

$$\text{then } f_c \text{ (compression stress)} = \frac{100 \times 2{,}240}{384} = 582 \text{ p.s.i.}$$

$$d = \frac{F.T^2}{AEQ} = \frac{224{,}000 \times 4 \times 4}{384 \times 750 \times 16} = 0{\cdot}78 \text{ in.}$$

$$\text{per cent deflection} = \frac{0{\cdot}78 \times 100}{4} = 19{\cdot}5$$

The deflection of 0·78 in. and particularly the percentage deflection would be too great in a unit of this nature, as a life of some 50 years may be required.

The same area of rubber can be maintained by incorporating steel plates bonded to the rubber as illustrated in Fig. 2 (b). In this case the area and Q factor are the same, but as each layer of rubber is in series a calculation must be made for the ½-in. and ¼-in. layers.

Consider ½-in. layer, then:

$$d = \frac{224{,}000 \times 0{\cdot}5 \times 0{\cdot}5}{384 \times 750 \times 16} = \frac{56{,}000}{4{,}608{,}000} = 0{\cdot}012 \text{ in.}$$

$$\text{per cent deflection} = \frac{0{\cdot}012 \times 100}{0{\cdot}5} = 2.4\dot{}$$

Consider ¾-in. layer then:

$$d = \frac{224{,}000 \times 0{\cdot}75 \times 0{\cdot}75}{4{,}608{,}000} = \frac{127{,}000}{4{,}608{,}000} = 0{\cdot}0274 \text{ in.}$$

$$\text{per cent deflection} = \frac{0{\cdot}0274 \times 100}{0{\cdot}75} = 3{\cdot}6$$

Total deflection of unit under load of 100 tons
$= (0{\cdot}012 \times 2) + (0{\cdot}0274 \times 2)$
$0{\cdot}024 + 0{\cdot}0548 = 0{\cdot}0788$ in.

The reason why a rubber block of sufficient thickness to give the 0·0788-in. deflection cannot be used is that it is governed by the shear rate, as follows:

The shear formula is $\frac{F}{AS} = \frac{\theta}{57{\cdot}3}$

where F = force, lb.;
A = cross-sectional area, in.²;
S = shear modulus (190 p.s.i.); and
θ = angle of deflection.

First, consider a 4-in. thick solid rubber unit, and deduce the force to move 10 deg.

$$F = \frac{384 \times 190 \times 10}{57{\cdot}3} = \frac{732{,}600}{57{\cdot}3} = 12{,}800 \text{ lb.}$$

The appropriate linear movement would then be

$$\frac{40}{57{\cdot}3} = 0{\cdot}7 \text{ in.}$$

To obtain the same movement with the sandwich rubber in which each layer is in series, the total thickness to move is $(0{\cdot}75 \times 2) + (0{\cdot}5 \times 2) = 2.5$ in.

Then, approximate angle =

$$\frac{57{\cdot}3 \times 0{\cdot}7}{2{\cdot}5} = 16 \text{ deg.}$$

$$\therefore F = \frac{384 \times 190 \times 16}{57{\cdot}3} = 20{,}000 \text{ lb.}$$

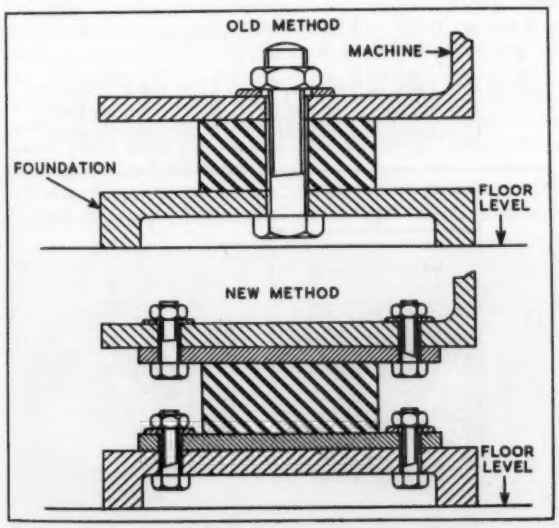


Fig. 1. Development of rubber for machine mountings. New method eliminates metal-to-metal contact.

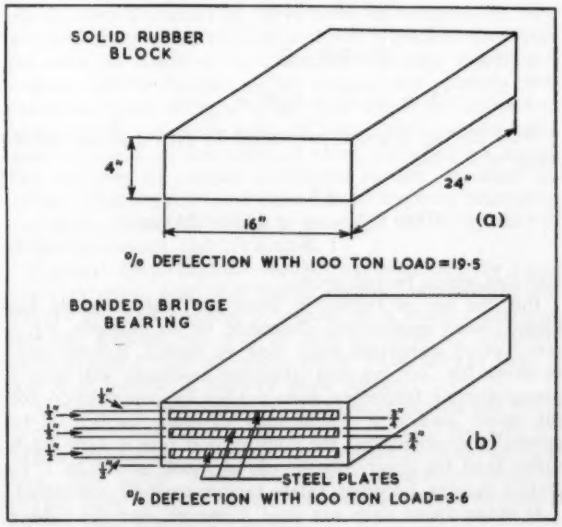
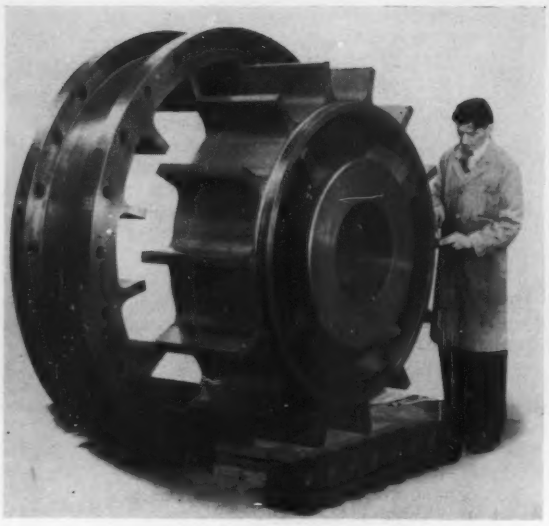
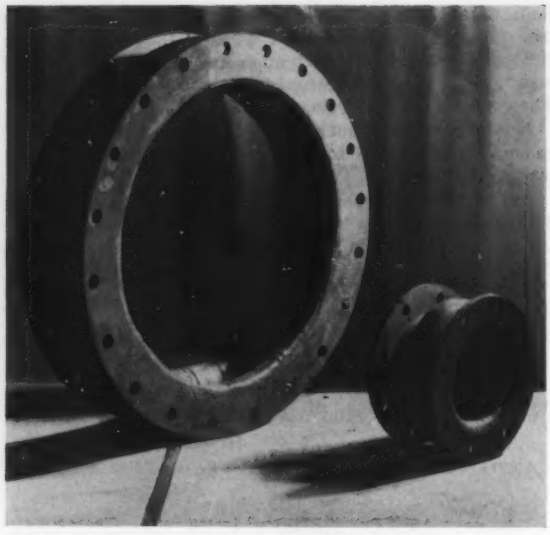


Fig. 2. How the introduction of steel plates can affect the degree of deflection produced by a given load.



Exploded view of Holset coupling, showing outer and inner members and rubber blocks.



Nylon-reinforced neoprene expansion pieces by André Rubber Co. Ltd.

From this it will be seen that by adding dividing plates the compression rate can be increased at a much greater rate than the shear rate and, by careful design and calculation, the rates can be varied to suit particular applications.

It should be further explained that if a solid rubber unit is used, of a thickness to give the desired compression rate under a certain load, the rubber thickness could be too thin to allow a movement of, say, 0·7 in shear, particularly as the angle of shear deflection for an application of this nature should be limited to between 10-15 deg.

This is illustrated as follows:

Deduce T with same area and same Q

$$\text{then } 0{\cdot}0788 = \frac{224{,}000 \times T^2}{384 \times 750 \times 16}$$

$$T^2 = \frac{0{\cdot}0788 \times 384 \times 750 \times 16}{224{,}000}$$

$$= \frac{362{,}880}{224{,}000}$$

$$T = \sqrt{1{\cdot}62} = 1{\cdot}28 \text{ in.}$$

Now deduce angular movement to give a linear movement of 0·7 in.

$$\text{Tan } \theta = \frac{0{\cdot}7}{1{\cdot}28} = 0{\cdot}55 = 27 \text{ deg.}$$

and this would be too great.

For the use of rubber in shear the basic formula has already been quoted and illustrated by an example, but a few further important facts may be useful. Rubber used in shear for, say, an anti-vibration mounting will give a lower natural frequency than rubber in compression for the same load and proportions of unit, as it can be generally accepted that the compression rate is very much stiffer than the shear—sometimes as much as 100 to 1. In certain designs, however, safety factors must be considered.

If entire shear units are used, however, and the rubber should fail, either through the rubber itself or through the bond of the rubber to metal, then serious consequences might result. This condition is often remedied by the use of units in part shear and part compression as in the case of motor-car engine mountings. The same remarks apply when rubber is used as a coupling between driving and driven member, but in such cases the rubber is usually used in pure shear and overload mechanical stops added to the design. There are many examples of this and a number of firms now employ rubber bonded to metal couplings in direct shear. Many couplings are also in use made up of rubber bonded to metal bushes assembled in a complete housing so that the actual rubber is in compression. The reason why a direct shear unit is used in preference to the bush type is due entirely to torsional resistance figures, in many cases such figures only being met by pure shear.

Using Rubber in Torsion

There are two ways of using rubber in torsion, i.e. the normal bush and the sandwich form, both of which are shown in Fig. 4.

The formula for calculating the stiffness of the bush form is:

$$\theta = \frac{T}{4\pi LG}\left(\frac{1}{(R_1^2)} - \frac{1}{(R_2^2)}\right) \text{ radians}$$

where θ = twist in radians; G = shear modulus;
T = torque in lb./in.; R_1 = inner radius;
L = length of rubber; R_2 = outer radius

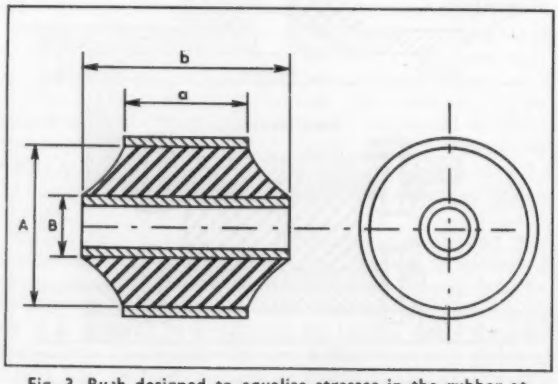


Fig. 3. Bush designed to equalise stresses in the rubber at the bond.

It should be pointed out that the most important point to consider in a design of this nature is the angle of displacement across the rubber as indicated by α. This should never exceed 30 deg. for normal use. If dynamic conditions prevail, however, then possibly deflections of around 10-15 deg. would be better. It is also necessary to give consideration to stress in the rubber and at the bond, and this is done by taking the torque, dividing by the radius and then dividing the final figure by the area, i.e., circumference × L.

Quite often bushes are designed as in Fig. 3 in order to equalise stresses in the rubber at the bond,

i.e., Circ. A × a = B × b

SANDWICH COUPLING—The normal sandwich type of coupling is quite common and can be obtained in varying designs. The formula for calculating the angle of twist is as follows:

$$\theta = \frac{583 \quad T.L}{N(D^4 - d^4)} \text{ deg.}$$

where θ = angle of twist;
T = torque, lb. in.;
N = shear modulus;
D = outside diameter, in.;
d = inside diameter, in.;
L = mean length of rubber, in.

The shear across the rubber, as shown in Fig. 3 is also an important factor and should be carefully checked. Shaping the rubber where it is bonded to the metal, in order to equalise stresses, is also important.

The usual shear stress permitted for designs of this nature, both bush and sandwich, is around 30 p.s.i. for normal loading and up to 60 p.s.i. for maximum load conditions, both considered in conjunction with the actual shear movement.

A few instances of how rubber units can be designed and calculated have been given, but it must be pointed out that the method of calculation is merely a basis for design and it is always wise for the design engineer to submit his final problem to an experienced rubber engineering organisation for confirmation or otherwise. Consideration should also be given by the design engineer to the finished article required, as complicated shapes, as in the case of castings or stampings, mean complicated tooling equipment.

Therefore, the more simple the design, the cheaper the unit, and for general purposes it may be taken that a rubber unit is akin to a casting except that in many cases where blind cores cannot be tolerated in metal casting it is possible to overcome this difficulty in rubber moulding by the stretching of the rubber. This, however, has a limit. It should also be appreciated that in the case of units composed of rubber and metal where the rubber is bonded, the metal parts must be located and all these facts have a bearing on the final design.

CIVIL ENGINEERING—Apart from rubber mountings for bridges to replace the normal rocker and roller, other applications include road expansion joints, where expansions of anything up to 10-12 in. can be accommodated, and jetties, where it has been proved that the most efficient resilient fendering, particularly for maintenance, is undoubtedly rubber. There are now several different types of units on the market such as the Raykin fender, designed in the U.S.A., the pure shear unit developed in the U.K. and a recent development employing a Swiss patent, namely the Neidhart system. Whereas the first two designs employ rubber bonded to metal, the latter unit employs cylinders of rubber encased in metal parts by means of preloading (not bonded) and the energy absorption is catered for by torsion of the unit. Units of both types can now be designed to cater for energy figures of around 50 ft./ton and having movements of up to 40 in. There is also a further design employing large cylinders of rubber in compression.

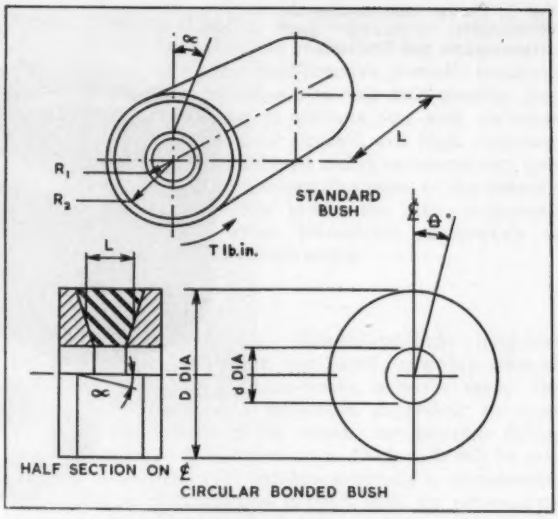


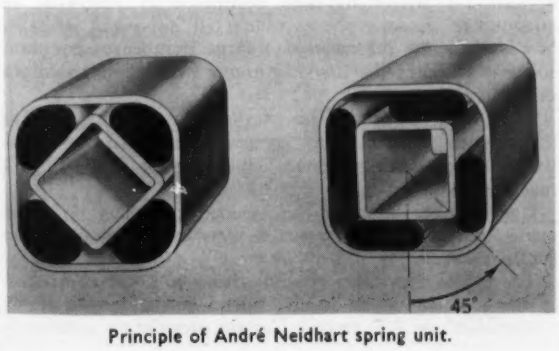
Fig. 4. Two methods of applying rubber in torsion.

Rubber is also now widely used for the mounting of hammer and other heavy machinery foundations.

MARINE ENGINEERING—There are now obtainable several designs of pipe expansion joints employing rubber reinforced with fabric; such units are capable (depending on bore diameter) of movements in compression, tension and shear of up to 4 in. and will withstand very high pressures in addition to complete vacuum conditions. Rubber units as flexible suction entries have recently been developed, these being of a bell type which are claimed to be easy to fit and much more efficient. They are now being used for main service tanks of ships and also for bilges. The majority of marine equipment is now mounted on rubber mountings of some kind, one of the most interesting uses being the rubber lining of propeller shafts in order to eliminate erosion and corrosion.

RAILWAY ENGINEERING—Rubber has been used for many years as draw gear and buffer springs, but railway engineers are now turning to rubber as a main suspension element. Rubber can also be used in order to eliminate metal-to-metal wearing parts which have always been a source of trouble in railway bogie design.

AUTOMOBILE ENGINEERING—The use of rubber has many applications, not only for window seals, etc., but also for engine mountings, couplings and bushes to avoid lubrication. The latest development—air suspension—employs rubber bags. Several papers have already been presented on this most interesting subject.



Principle of André Neidhart spring unit.

The author wishes to thank the directors of the André Rubber Co. Ltd. for permission to publish this article.

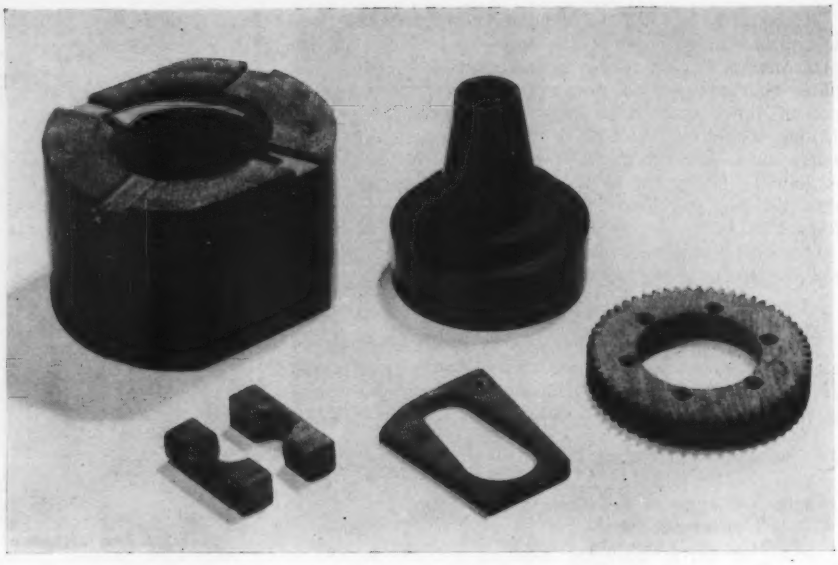


Fig. 1. Typical asbestos-phenolic components, including gear, steam nozzle and fairleads.

NEW USES FOR HIGH-PRESSURE ASBESTOS-PHENOLIC LAMINATES

Of the materials which combine corrosion resistance with mechanical strength, atmospheric mixes of asbestos-phenolics have had considerable success in recent years. High-pressure laminates, the latest development in this field, are discussed here

INDUSTRY lacked for many years a material with sufficient mechanical strength to be used as a true constructional medium combined with inertness to organic solvents and high corrosion resistance. Many materials have been used in the past, but most of them, i.e., stainless steel, nickel alloys and certain ceramics, have not proved to be entirely ideal for the purpose.

A very common practice in the chemical plant industry is to use a cheap, mechanically-strong material such as mild steel or cast-iron and to provide it with a coating of material which lacks strength but has high corrosion resistance. Among the best known in this category are the glass enamels, rubber and related materials, and lead. The former is used extensively where purity of product is important; solvent resistance is complete, acid resistance is of a very high order and alkali resistance is by no means negligible; susceptibility to mechanical and thermal shock is the principal objection and failure of a coating frequently results in complete loss of the piece of plant concerned, by unseen corrosion. Lead has its limitations as a corrosion-resisting material and is not much used in the food, beverage, pharmaceutical and fine chemical industries where its toxic nature renders it unsuitable. Solvents are generally inimical to rubber.

Plastics have provided a new series of materials, the best known and most characteristic being the thermoplastics. Among these the polyethylenes have become extremely important as a result of their indifference to acid and alkali, two notable polyethylene analogues being polytetrafluoroethylene (p.t.f.e.) and polytrifluorochloroethylene (p.t.f.c.e.), both of which are very costly.

The polyethylenes are characteristically pliable in low molecular weight form, increasing in rigidity with increasing molecular size, but essentially rather waxy, deformable materials with low maximum working temperatures and a tendency to fail in the presence of certain solvents, such as the aromatic hydrocarbons. Polyvinyl chloride has attained considerable importance both as a plasticised pliable material, with properties similar to polyethylene, but lower solvent resistance, and as unplasticised rigid material which is particularly useful for ducts, fan blades and similar applications where its high resistance to corrosion in aqueous or gaseous phases renders it important. It fails, however, in the presence of a large number of common solvents and has the low maximum working temperature of its class.

The other group in the plastics class is that of the thermosetting resins. These generally are hard, comparatively heat-resisting materials which can be moulded and machined with exactness.

Considerable attention has tended to focus on these resins, particularly the epoxies, the melamines and the furan resins.

There has, however, recently been a notable increase in the interest shown in the phenol-formaldehyde resins ("phenolics" or P.F. resins). Certain proprietary corrosion-

resisting coatings rely on phenolics for their desirable properties, and considerable success has been obtained with atmospheric and low-pressure "pudding" mixes of phenolics with asbestos or carbon which have the great advantage of being mouldable, either alone or on steel supports, without high pressures and temperatures.

The latest interest in the phenolics, however, is associated with high-pressure asbestos-phenolic laminates. These laminates have arisen essentially as materials of construction in the mechanical engineering and aircraft industries. They take their place with the cotton and other fibre laminates and have tended to be overlooked as primary materials for chemical engineering largely as a result of their better known associations.

One or two manufacturers have employed these asbestos-phenolic laminates with notable success in specific applications, such as in small filter-press bodies and plates, and for pump impellers, but general applications do not appear to have been hitherto sought. A serious move to exploit the chemical and mechanical properties of asbestos-phenolic laminates as materials of construction for the chemical industry has now been made by collaborative action on the part of Coin Insulation Ltd., who specialise in the machining of resin laminates, and Laminated Plastic Products Ltd., a subsidiary of a well-known pharmaceutical and chemical manufacturing company.

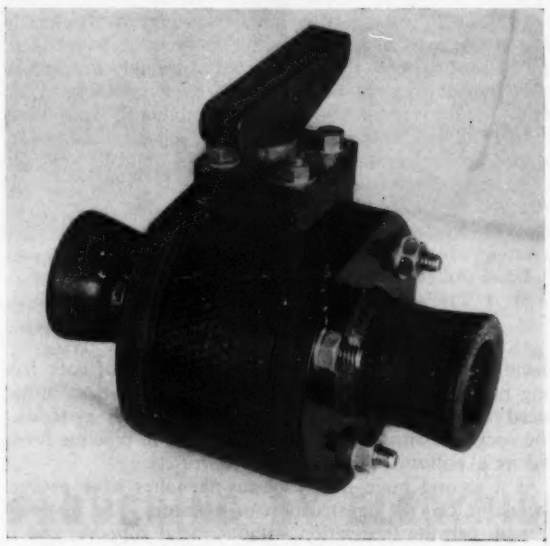


Fig. 2. Ball-type plug cock in asbestos-phenolic laminate, with p.t.f.e. seals.

The view is taken that high-pressure phenolic laminates are of outstanding importance in this field because they combine great resistance to solvents and acid corrosion with outstanding mechanical strength and high maximum working temperature. Combined with a comparatively low-cost factor, arising from intrinsic cheapness of the phenolic resins, these good qualities render the asbestos-phenolic laminates potentially most formidable competitors to traditional materials of construction.

Main Properties

MECHANICAL PROPERTIES—Asbestos-phenolic laminates are divisible into two types, one based on woven asbestos cloth and the other on non-woven asbestos mats. The former have mechanical properties dependent to some extent on the fineness of the weave, but generally falling into a definite group as indicated in Table 1. It will be seen that the non-woven type exhibits generally a considerably higher degree of mechanical strength than the woven type. For comparison, there are also shown figures claimed for "dough" mixes of phenolic resin with random asbestos fibres. It will be immediately apparent that lack of mechanical strength is inherent in this type of material, rendering it necessary to employ massive mouldings or metal strengthening supports.

THERMAL PROPERTIES—Asbestos-phenolic laminates are relatively poor conductors of heat, a property which rather restricts their use in heat exchangers other than for outer shells, headers, etc. They are virtually immune to the effects of thermal shock; in this, as in freedom from mechanical fragility, they score heavily against stoneware and enamel-lined metal.

They have a maximum working temperature (175 deg. C.) above the general run of reinforced thermosetting resins, particularly their closest rivals, the glass reinforced epoxy resins, which are not generally considered to be usable above 160 deg. C.

CHEMICAL PROPERTIES—The chemical resistance of the asbestos-phenolic laminates exhibits the very widest variation between manufacturers' grades. Generally, chemical resistance increases with increased pressure of moulding (curing pressure), and is better with non-woven mat reinforcement than with woven cloth reinforcement. Attack by aqueous acid, though sufficiently slow to be generally negligible, occurs by attack on asbestos fibres which can be slowly leached out, with loss of mechanical strength. Where immersion conditions are extremely severe, such as prolonged contact with boiling hydrochloric acid over

TABLE 1. Mechanical properties of laminated asbestos cloth and mat, and "dough" mixes

	Tensile Strength (p.s.i.)	Compressive Strength (p.s.i.)	Cross-breaking Strength (p.s.i.)	Shear Strength (p.s.i.)	Young's Modulus (p.s.i.)
Asbestos Cloth Laminates					
A (coarse)	7,000	34,000	11,000	10,000	$1{\cdot}2 \times 10^6$
B (coarse)	7,000	28,000	6,000	5,000	—
C (intermed.)	8,000	20,000	20,000	15,000	$2{\cdot}5 \times 10^6$
D (fine)	12,000	42,000	19,000	12,000	$1{\cdot}5 \times 10^6$
Asbestos Mat Laminates					
E	22,000	50,000	23,000	16,000	$1{\cdot}7 \times 10^6$
F	25,000	50,000	35,000	19,000	$3{\cdot}1 \times 10^6$
G	29,000	60,000	23,000	15,000	—
H	20,000	76,000	38,000	19,000	$3{\cdot}2 \times 10^6$
"Dough Mixes" with Asbestos Filler					
I	6,000	38,000	10,000	9,000	$1{\cdot}5 \times 10^6$
J	2,500	10,000	—	4,000	$1{\cdot}0 \times 10^6$
K	3,000	10,000	5,000	—	$1{\cdot}4 \times 10^6$
L	2,000	8,000	—	3,000	$1{\cdot}0 \times 10^6$

many days, grades are generally employed which are based on blue asbestos (crocidolite). The use of crocidolite brings its own problems, such as greatly increased difficulty of machining, but the resulting laminates become nearly indestructible.

Non-aqueous hydrogen chloride, e.g., in the presence of solvents or vapours, is virtually without effect on asbestos-phenolic laminates of good grade. The most interesting condition to which asbestos-phenolic laminates are exposed freely and without harm is the very difficult but commonly occurring combination of solvents and acid corrosives together. Generally this combination calls for glass-enamelled iron or steel, but it has been demonstrated that asbestos-phenolic laminates are equally effective.

Oxidising acids such as concentrated nitric acid are inimical to phenolic resins and are strong contra-indications. This is a real difficulty and one not likely to be overcome.

Most grades of phenolic resin are attacked to some extent by prolonged contact with cold concentrated or hot dilute caustic alkalis, but development work at present being carried out is demonstrating that new grades can cope with this difficulty and it has also been shown that post-machining impregnation techniques confer greatly increased caustic alkali resistance on existing grades. The asbestos-phenolic laminates share a not complete resistance to caustic alkali with glass, glass enamel and stoneware.

Applications

As mentioned above, filter press components and pump impellers have been manufactured for several years. The new commercial venture, appreciating that new potential uses will be discovered almost daily, is concentrating at first on a ball-type plug cock, manufactured in asbestos-phenolic laminate with p.t.f.e. seals. This type of cock has long been known in aircraft fuel lines and has been introduced by various manufacturers in traditional materials. The cock, shown in Fig. 1, has been made in pipeline form and as a bottom outlet control for vessels.

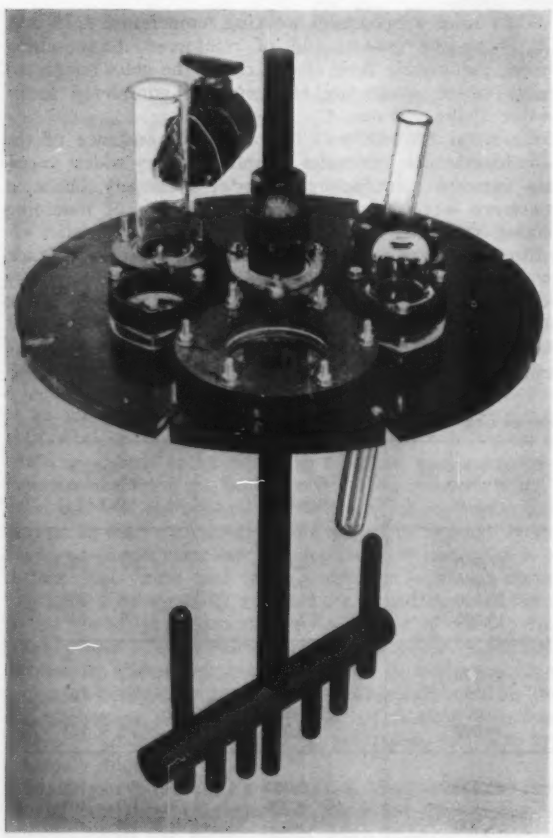


Fig. 3. Rake-type slow-speed agitator for 20-gal. reactor.

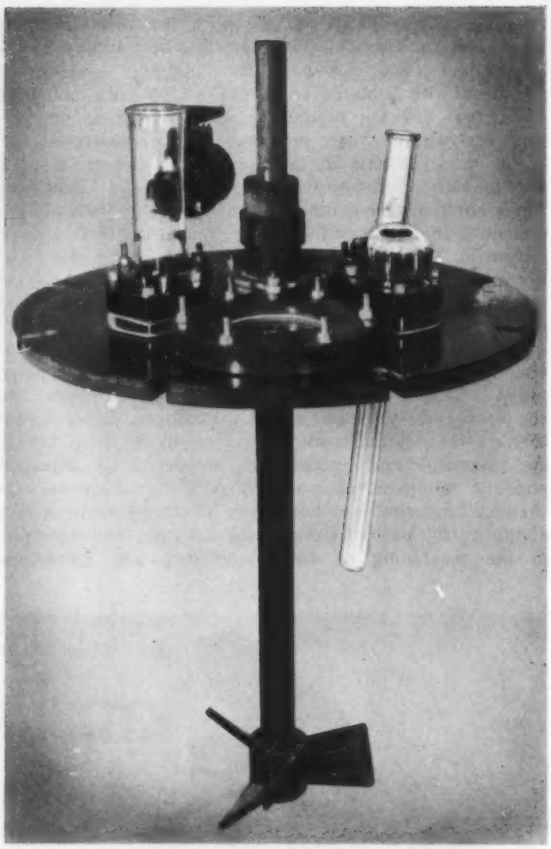


Fig. 4. Asbestos-phenolic three-bladed impeller, produced as a replacement for the standard enamelled-iron component.

As a second main line, asbestos-phenolics have proved invaluable for the construction of agitators. The material strength permits fabrication without metal supports and a great variety of types have already been produced. Fig. 3 shows a normal-type three-bladed impeller produced as a replacement for the enamelled-iron component supplied as a standard fitting with the 20-gal. "sulphonating pot" type of digester; a cover for the same vessel is also shown.

Dip pipes, sufficiently rugged to withstand mechanical maltreatment and yet be solvent and corrosion resistant, have been found to be ideally manufactured from asbestos-phenolic laminates.

The early application to filter press components has now been followed by the fabrication of light, indestructible filter plates for large stoneware filters, replacing stoneware plates of many times their thickness and grievously susceptible to thermal shock. Line filter cases have also been produced and built-up tower packing support plates of 60 per cent free space and prodigious weight-carrying capacity have become available.

Generally, the realisation of the usefulness of these asbestos-phenolic laminates in the chemical industry has come as a distinct shock in view of the considerable period during which they have been available. The new collaborative venture is finding its chief embarrassment in too great a flood of ideas.

P.V.C. PIPES COMBAT CORROSION

THE life of cast-iron or steel pipes is frequently a serious problem in chemical factories, but a more widespread difficulty has occurred with pipes laid underground, where inspection and maintenance are extremely costly. Gas and water mains laid in acid soils or subject to certain bacteria have been known to fail within twelve months of laying.

Ten years ago the Ministry of Health set up a departmental committee to consider the problem raised by the widespread loss and inconvenience caused by the corrosion of iron (and steel) water pipes.

In 1950, this committee issued an interim report which underlined the serious nature of the problem in very considerable detail and concluded by recommending further research, mainly on protective measures, but omitted to suggest research on alternative materials to iron and steel.

Ordinary rigid p.v.c. has been available as a material for pipe construction for a number of years. However, until recently, little headway could be made with promoting its industrial use in Britain, although it has been widely employed on the Continent for a long time. In view of the poor response in this country, it was decided to postpone the attack on industry and to pursue research until a new material of unquestionable suitability had been found. This aim is now claimed to have been achieved with the development of Geon RA.170, which combines corrosion resistance with a number of other important properties, the most outstanding being its high-impact strength. This material, which contains no plasticiser, has an impact strength about fifteen times that of ordinary rigid p.v.c. and, unlike some other rigid plastics and cast-iron, it does not shatter. It is primarily this high-impact strength, coupled with its natural resilience and resistance to corrosion, that makes this new form of p.v.c. of interest as a pipe material for water and gas mains as well as other services.

The low density of p.v.c. (1·36) gives a pipe weight which is less than one-fifth that of iron or steel, and even lower when compared with copper or lead.

P.V.C. pipe can be produced in any required length. Generally 16-18-ft. lengths are employed, though lengths of 43 ft. have been handled in this country. There is one recorded instance of a 600-ft. length of 3-in. pipe being delivered as a single unit along a canal system in Holland.

Average limits for permanent working pressures are as follows: 1 in., 200-300 p.s.i.; 3 in., 100-200 p.s.i.; 6 in., 100-150 p.s.i.; 12 in., 50-100 p.s.i.

As high-impact p.v.c. is a thermoplastic material, pressure rating falls as temperature is increased. Allowances of the following order must be made: at 20 deg. C.—as specified; at 40 deg. C.—75 per cent of rating; at 60 deg. C.—40 per cent of rating.

An interesting claim for p.v.c. pipes is that the pressure losses are lower than with iron or steel pipes and this is due to its smooth bore and non-corrodibility.

An important part of the research into pipe materials is the investigation into the manufacture of pipe fittings, and a detailed study of the injection moulding process has been made by the British Geon research and development department. The flow characteristics of the p.v.c. compound in relation to temperature and pressure are of prime importance; it has also been emphasised that the extruding equipment must also be suitable. A recent paper by C. A. Brighton (*Brit. Plast.*, **31,** November 1958, pp. 468-72, 495) discusses these points and suggests methods of adapting conventional machines for use with the new p.v.c. polymer. A number of manufacturers are now producing a wide range of fittings in high-impact p.v.c. and pipes up to 18 in. bore and rod stock for machining are available. A particularly important application is for effluent pipes and already successful installations have been laid at the Atomic Energy Establishment (Aldermaston) and at several oil refineries.

Manufacturers of pipes and/or fittings in high-impact p.v.c.: B.T.R. Industries Ltd., Chemidus Plastics Ltd., Durapipe Ltd., Extrudex Ltd., Formica Ltd., Moseleys Ltd. and Yorkshire Imperial Metals Ltd.

PLOUGHING BY ELECTRICITY

THE contract for Britain's first electrically-powered tractor was recently placed with the Carron Co.

This tractor consists of a 30-h.p. squirrel-cage induction motor, a hydraulic transmission system, two land wheels driving in tandem and a third outrigger wheel which, besides acting as a stabiliser, serves to carry the cable drum and winding gear. Mounting is in a tube and channel chassis, with ploughs fore and aft.

Electric supply is drawn from the grid through a transformer. Current is three-phase, 415 volts, 50 cycles. The distribution line is arranged so that maximum land on either side can be reached by the tractor.

The low-speed high-torque Staffa hydraulic motors are mounted directly in the driving wheels and are supplied from a Derri sine three-stage hydraulic pump which, in turn, is driven by the electric motor. Either of the driving wheels is steerable, depending on which one is leading.

Twisting and dragging the cable is avoided by a sideways movement achieved by locking both wheels in one direction and crabbing over to a new lay.

The cable is paid out or wound in as the tractor moves away from or towards the power source.

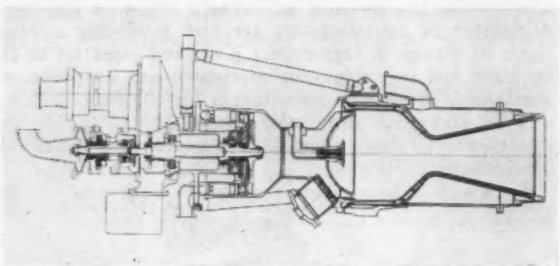
The all-up weight of the tractor is 4½ tons. Its maximum tractive effort using both motors is 3,200 lb. at 1,500 p.s.i. and, with one motor, 1,600 lb. at 1,500 p.s.i.

SELECTING MATERIALS FOR ROCKET MOTORS

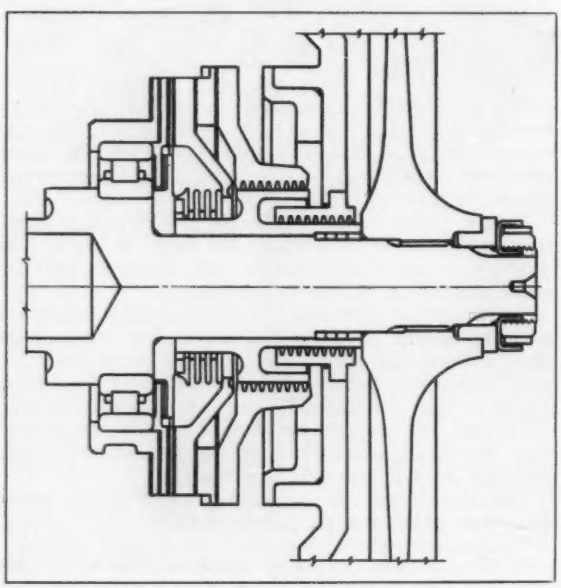
DURING a recent lecture by Mr. W. N. Neat,* B.A., A.F.R.Ae.S., on the development of the Spectre rocket engine, a few of the problems involving material selection were discussed. The Spectre is an H.T.P. (hydrogen peroxide) and kerosene-fed engine designed for the mixed power formula in manned aircraft, and a version of this engine is installed in the Saunders-Roe SR.53.

The Spectre was developed from the Super Sprite, which is used as a J.A.T.O. unit for the Valiant bomber, and, as a self-contained unit, may be jettisoned after take-off and parachuted to earth using air bags to cushion the actual landing shock. In the development of the Spectre, corrosion problems and compatibility with H.T.P. fuel necessitated a thorough investigation into the materials which could be used.

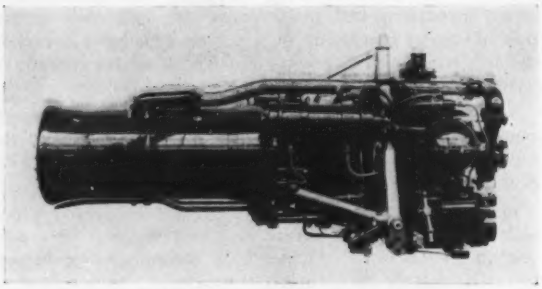
The original combustion chamber with its convergent-divergent nozzle was machined from stainless steel with external helical fins for efficient circulation of H.T.P. for cooling purposes. The external light-alloy casing forming the outer walls for this circulation fluid was clamped to the combustion chamber. In the latest version of the engine the fins are made integral with the light-alloy outer casing while the material of the combustion chamber itself has been changed to an alloy much more resistant to deformation under the high temperatures prevailing.



Section through Spectre engine, showing combustion chamber and turbine drive.



Labyrinth seals, showing successive stages.



Mark 5 Spectre rocket engine.

The H.T.P. is pumped via the cooling passages around the combustion chamber to a second-stage pump which raises the pressure before it is fed to the silver-plated catalysts in the head of the combustion chamber. The pumps for lubricating the bearings and for both H.T.P. and kerosene fuels are driven by a turbine powered by a bleed from the H.T.P. feed line. One of the most difficult problems was to achieve sufficiently reliable sealing to ensure that the H.T.P. (either in liquid or decomposed form) did not mix with the kerosene or the lubricating oil. Successive stages of labyrinth seals reduced the pressure of the H.T.P. "steam" along the turbine shaft and a final positive seal was made by a lubricated carbon ring rubbing against an abutment on the turbine shaft mounted on flexible bellows.

During deliberate mishandling tests, it was apparent that, under certain conditions, oil in the gearbox could be contaminated by the H.T.P. leaking past the pump seals, and these were therefore repositioned between the H.T.P. pump bearings, the conventional bearings on the H.T.P. side being replaced by unplasticised p.v.c rod bearings lubricated by hydrogen peroxide itself. Other types of bearing, such as synthetic glass-bonded p.t.f.e. bearings, have also been satisfactorily used.

The starting device on the engine necessitated the use of a piston actuated by the pressure of decomposed H.T.P. and here difficulty was experienced by the high inherent friction of the piston assembly which was overcome by a film of p.t.f.e. dispersed in the cylinder walls.

In the initial flight test stage, the H.T.P. tank of light alloy was p.v.c.-lined and the underside of the Canberra bomber used for test flying was covered with a thin sheet of stainless steel to protect the structure from heat effects. To gauge the approximate temperature adjacent to the jet efflux, sticks of solder of varying melting points were suitably mounted, and from these some idea of the maximum temperatures achieved during flight was attained.

The latest version of the Spectre, known as the Mark 5, incorporates many modifications initiated by earlier tests and uses, in many cases materials different from those employed in earlier versions. The different versions of the actual engine range from those capable of continuous running to those designed for short operational cycles as used for assisted take-off purposes, and each of these engines has its own particular material problems. In the course of the development, higher power outputs for less weight have been achieved, together with longer life, a process which would not have been possible without the continuous development and improvement of the basic materials.

* *Chief engineer, rocket division, de Havilland Engine Co. Ltd.*

PRESSURE VESSEL DESIGN

Pressure vessels designed to the present code of practice can be uneconomical from many points of view. In this article, the author discusses the main factors necessary to ensure safety in rational design

by R. T. ROSE, B.Sc., Ph.D.*

IN designing a pressure vessel, as in any other engineering structure, it is logical to consider in what manner failure might take place and to ensure against its occurrence. This means that all the possibilities of failure must be examined and each in turn made sufficiently remote.

It is by thinking along these lines (in supplementing the rather arbitrary principles adopted in the codes) that pressure vessel design may incorporate economy with safety and a great deal of work has been done towards this end both in the U.K. and abroad. In particular, Commission XI of the International Institute of Welding has been actively engaged on this topic[1] and has produced some important proposals. Papers in the U.S.A. by Murphy, Soderberg and Rossheim[2] and Kooistra[3] make contributions to this study.

These papers urge that on the basis of this rational approach to design it is clearly evident that an increase in design stress is permissible in new designs. Besides the resultant saving in cost of pressure vessels, service conditions that present difficulties in design would be more easily handled, and the limit of possibility would be lifted. Furthermore, new materials could be used to their best advantage with less risk either of failure or of over-conservative design and its economic penalty.

Pressure vessel, subjected to 2×10^6 pulsations of pressure from 100 to 1,300 p.s.i., which eventually failed under steady pressure at 4,450 p.s.i. by brittle fracture from a fatigue crack.

Modes of Failure

The possibilities of failure to be considered are all those recognised in the past, i.e., elastic deformation; plastic deformation, perhaps leading to ductile rupture; creep deformation, perhaps leading to creep rupture; fatigue failure; brittle fracture; and corrosion.

Deformations, which in themselves may not constitute failure in other structures, may be impermissible in pressure vessels on the grounds of causing leakage at mechanical joints, such as bolted flanges, manhole seatings or expanded water tube connections, or because deflection (and therefore load) is transmitted to supports or attached pipework. Deformation due to thermal expansion must be considered under this heading. Further, a vessel subject to internal pressure can be a non-linear system, in which an increase in diameter (or surface area) results in an increase in load and thus stress. Severely deformed areas, besides being unsightly, may well indicate that instability and rupture are not too remote.

In fact, it is very unlikely that such gross deformation could occur under normal operating conditions and, similarly, ductile rupture would only have to be considered in cases where, for instance, there was a remote possibility of the vessel contents exploding without provision for relief of pressure. In general, ductile rupture or bursting does not represent a limiting design criterion.

In contrast, the effects of creep and of fatigue damage represent very real hazards to the serviceability of a vessel, and the latter in particular has been the subject of considerable research. Brittle fracture is again a real hazard, but differs from these in so far as it is not a long-term effect. Whilst the type of stress system plays some part in determining whether a fracture is brittle (and therefore it is helpful to eliminate notches and discontinuities in the design) the presence of both welding residual stresses and possible weld defects is likely to be of greatest importance. Where neither of these can be removed, it is desirable to use a material shown to be ductile in a suitable test at the working temperature. The effect of uniform corrosion is safeguarded by the provision of an allowance on thickness calculated to outlast the life of the vessel. When the contents of a vessel may cause stress-corrosion of the chosen material, the peak stresses must be limited to a value below which stress-corrosion cannot occur. Tests have shown that stress-corrosion takes place in steel primarily when it has been yielded and remains in a stressed condition. Kerkhof[4] proposes that by limiting the peak stresses, as calculated by an elastic analysis, to a value equal to twice the yield point, there is no possibility of repeated yield and therefore no danger of stress-corrosion.

* *In charge of pressure vessels department, British Welding Research Association.*

The contents of a vessel, or the surrounding atmosphere, may influence its resistance to repeated loading by the mechanism known as corrosion-fatigue. It has been found that certain media in contact with steel can cause a drastic reduction in its fatigue resistance, out of all proportion to the loss in cross-sectional area due to corrosion alone. In such tests it is sometimes observed that there is no endurance limit, but this is of little importance in pressure vessels, since there is seldom a necessity to withstand an indefinite number of pressure applications.

Design against Failure

The steps that can be taken to prevent excessive elastic deformation depend on an ability to calculate with fair precision the stresses occurring in the complex shapes met in pressure vessels. How far this is possible today is discussed later in the article. When stresses are locally above the yield point it is still possible to use elastic analyses in some instances. Also where there is a possibility that parts of the vessel may be connected only by material suffering plastic deformation, the stresses must be kept below the value which just causes yielding through the full plate thickness, and again an elastic analysis would predict the deformation with reasonable accuracy. A rudimentary plastic analogy with the bending of beams is proposed[1] to prevent full-section yielding.

Design against excessive creep deformation, or rupture, and against fatigue failure, for regions of stress concentration, presents greater difficulties.

Although the creep rates in the two principal directions in a uniform two-dimensional stress system (e.g., a thin cylinder under pressure) may be predicted from a knowledge of the creep rate in a uni-axial specimen, the behaviour of a body in which sharp stress gradients exist is complicated by relaxation and redistribution of stress. In the former case, creep cannot result in a stress relaxation, and the stresses must be limited to cause no more deformation than is considered permissible. In the latter case, a complete analysis is not possible, and at present it is only by an intuitive approach based on experience that the designer can say whether deformation is likely to be serious. In fact, his decision will be based on a knowledge of the extent of the stress concentration in relation to the plate thickness. With regard to creep rupture, under uniform or non-uniform combined stress very little is known. It has been suggested[5] that creep rupture under uniform combined stress depends on the equivalent stress based on the shear strain energy criterion. Because relaxation modifies the peak stresses at a discontinuity, for this case, the equivalent stress causing rupture would be calculated from the mean stresses existing in the body of the material, using experimentally determined factors, rather than the elastic stress concentration factors. Obviously, the relationship between these factors would vary widely with the type of stress system.

A similar situation exists in fatigue failure. It is found that if the nominal stresses to cause failure in smooth and notched specimens at a certain number of cycles are compared, they are not in proportion to the (elastic) stress concentration factors of the notched specimens. The proportionate reduction in fatigue strength due to the notch is less, in general, than the stress concentration factor, and is termed the fatigue strength reduction factor, k_f. This factor is related to the stress concentration factor, k, by means of the quantity called the notch sensitivity index,

$$q = \frac{k_f - 1}{k - 1}$$

This latter quantity has, so far, only been established by experiment and is found to vary with the material, the stress gradient and the number of cycles at which the comparison is made. The influence of the stress gradient is illustrated by a change in the notch sensitivity index when specimens having the same ratio of peak to nominal stress, but different stress gradients, are tested under repeated loading. Additionally, there is a size effect in fatigue, as shown by testing unnotched speciments of similar form but different size, cut from the same parent block.

Pulsating pressure fatigue tests now being performed at B.W.R.A. will provide values of strength reduction factors for the nozzle designs under investigation. It will be helpful to deduce from these results the notch sensitivity indices and to relate these to the known stress distributions. However, it is not possible to refine design against fatigue failure in this way at present. Where values of elastic stress concentration factors are known, it could be assumed that the stress concentration developed its full effect (i.e., $q = 1$). This would lead to an under-estimation of the fatigue life, if the life of the vessel were calculated on a basis of uni-axial pulsating tension tests on full-plate thickness material, with surfaces in the as-received condition.

At temperatures up to 350 deg. C. there is not much change in the fatigue resistance of steels. Above this temperature, creep begins to take effect, and there is very little information available on fatigue strength. In pressure vessels, creep causes a relaxation of the statically-indeterminate peak stresses, and this has an adverse effect on strength. Although the *absolute* stress after relaxation is less, the *stress-range* on release of pressure is unaltered, so that reverse yielding in the cold condition is a possibility. This is shown in Fig. 1. The effect of relaxation is therefore to increase the plastic strain range per cycle, with consequent reduction of the number of cycles to failure. The effect is aggravated by the length of time in the hot condition and, of course, whilst the number of cycles to failure is reduced, in a laboratory test the life measured in hours is very much increased. Testing is therefore a long-term investigation.

Fatigue crack at a protruding nozzle. A brittle fracture (coarse, crystalline area at left) and a ductile failure (silky, white area at top) took place on breaking open the specimen to reveal the fatigue crack (dark area).

Fatigue in Pressure Vessels

The recent report[6] of failure of some steam accumulators used in the catapulting of aeroplanes is one of the best documented examples of fatigue cracking in pressure vessels to be found in the literature. Failure took place in each vessel at the steam inlet-outlet nozzle in the drum, by cracking around the periphery of the reinforcing collar. The cracks commenced at the toe of the fillet weld and penetrated into the wall of the drum, as shown in Fig. 2. Cracks were also found around the manholes, but no details are given. The vessels had been in service for about one year, and although no estimate of the total number of pressure cycles was given, it was stated that nearly all cycles had been performed at a pressure less than half the design working pressure. The severe thermal cycling associated with each pressure cycle, and possibly the reaction of the manifold piping due to restraint of thermal expansion, must have contributed to the failures, since fatigue tests using pulsating pressure on nozzle details, performed by B.W.R.A., would suggest that the designs should have resisted more than a million cycles at the low pressures used. Examination of the nozzles after failure showed that the fit-up of the reinforcement was not good, but this must be regarded as only a secondary factor in the failure. The primary cause of failure was of course, that the high local stresses at the nozzles and the definitely cyclic nature of the loading, made the design unsuitable on the grounds of premature fatigue failure.

Recently, two investigations have been reported that are of some help in estimating the probable fatigue resistance of pressure vessel details. Kooistra[3] has very conveniently summarised the work of the U.S. Pressure Vessel Research Committee on plastic fatigue of pressure vessel materials and considered how this work can help the designer. Both the high values of local stresses and the relatively low frequency of pressure applications in pressure vessels make it necessary to confine fatigue investigations to life values of a few thousand cycles. For this, the material must be stressed into the plastic range and it is then convenient to record results in terms of strain rather than stress. Two types of specimen were tested. One was a cantilever which could be deflected through a constant range, the other was a rectangular plate loaded by pulsating hydraulic pressure on one side. A range of steels from a commonly-used mild steel to various high-strength low-alloy steels was tested, and the broad correlation of strain range to cause failure at 10^5 cycles with U.T.S. is a result of importance in deciding the advantage to be gained in the use of the stronger steels. In this correlation, it is shown that the strain range is approximately proportional to U.T.S., so that the high ratio of yield strength to U.T.S. in the stronger steels appears to confer no advantage in fatigue strength.

By comparing results for as-rolled specimens with those for ground specimens, it was found that the nominal strain-range for as-rolled surfaces was reduced by a factor of 1·6 relative to the ground specimens, for equal numbers of cycles to failure. Small machined notches (0·06 in. deep) produced a value as high as 3·8 for this factor and its value for simulated nozzles in model vessels was found to be 4·7. This factor, which Kooistra calls the "effective strain-raising factor", is closely akin to the strength reduction factor used in normal long-life fatigue testing and, in fact, Kooistra suggests that it should be used to calculate the nominal (or design) stress. Thus, if e_N is the strain range to cause failure in a ground specimen at N cycles and k_f is the strength reduction factor, then the maximum design stress permissible in relation to fatigue failure in N cycles would be

$$\frac{e_N E}{k_f}$$

where E is the modulus of elasticity. Unfortunately, values

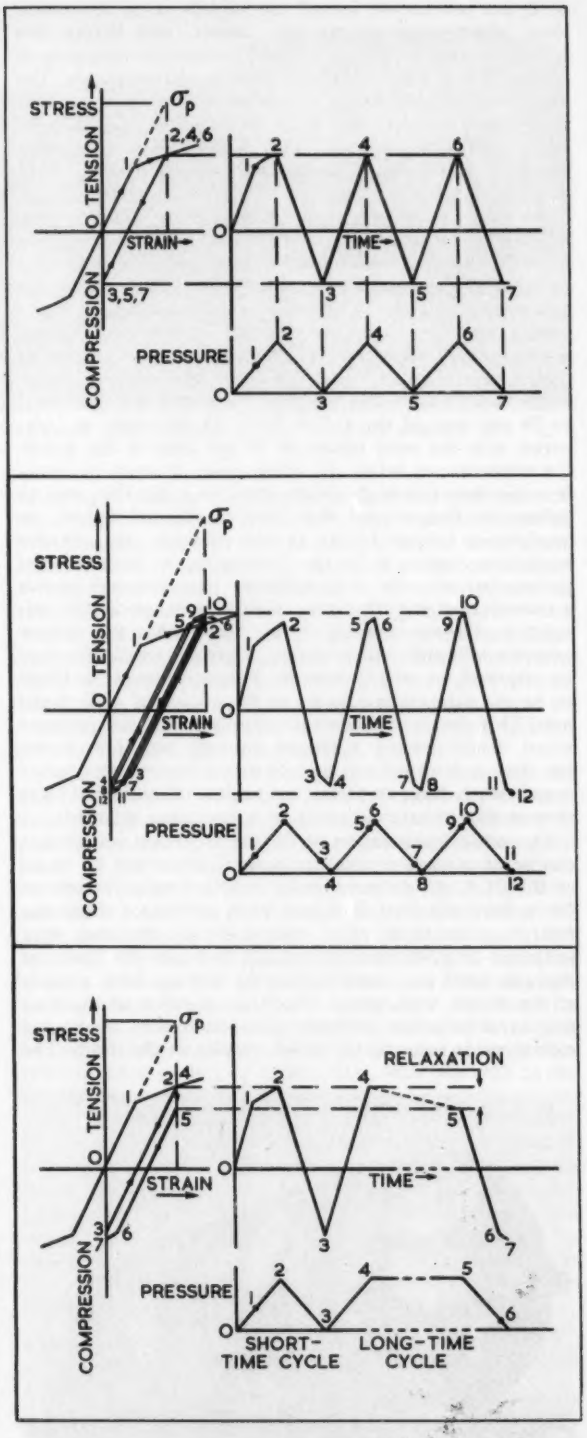


Fig. 1. "ω-stressing".

Idealised behaviour at regions of high peak stress, σ_p, during repeated applications of pressure.

Top—A peak stress less than twice the yield point is accommodated with negligible strain-hardening.

Centre—A peak stress greater than twice the yield point causes yield and reverse yield, with excess strain-hardening.

Bottom—When the temperature is sufficiently high, creep relaxation produces reverse yield on release of pressure, with consequent strain-hardening.

of k_f are not known for all the various stress concentrations which arise in pressure vessels, and before this formula could be used in design it would be necessary to fatigue test a wide variety of details and materials. The amount of testing could be limited if a correlation were established between the stress distribution and strength reduction factor, but this in turn would require a far more extensive knowledge of stress distributions than we have at present.

An ability to design details against fatigue failure in such a quantitative manner is a most desirable objective, but plainly this is not yet a possibility. Kooistra suggests that to safeguard against failures a sufficiently large value, say a tentative value of 4, of the strength reduction factor should be chosen, and it will not discriminate against normal detail design criteria. With this factor, a table of design stresses is calculated for a 100,000-cycle life. These range from 37 per cent of the U.T.S. for the mild steel to 30 per cent of the U.T.S. for a 58 ton steel, as compared with the code values of 25 per cent of the U.T.S. for temperatures below the creep range. It must be borne in mind that this high design stress is applicable only to failure by fatigue and that other modes of failure, or accelerated fatigue failure in the presence of corrosive media, may prove to be the limiting factor. Furthermore, the number of cycles to be withstood in service may permit a reduction of the 10^5 cycles taken as a datum in this calculation, thereby making it less likely that the fatigue criterion will rule. Alternatively, a greater cyclic life may be required, in which case the fatigue criterion is likely to be the determining factor in the choice of wall thickness. This design procedure is adequate only for pressure vessel details having a fatigue strength reduction factor less than 4. It would not be safe to assume that this factor is sufficiently large to permit the neglect of additional local stresses due to external loads or temperature gradients.

The other investigation of fatigue failure in vessels that can be of assistance in design is that carried out by Lane[7] at B.W.R.A. on pressure vessel nozzle details. Vessels of 20 in. bore and 1 in. thickness, each carrying a single unreinforced branch of $6\frac{7}{8}$ in. bore and $\frac{3}{8}$ in. thickness, were subjected to pulsations of pressure between the limits of 100 and 2,000 p.s.i. until failure, by leakage from a crack at the nozzle, took place. The basic purpose of the tests was to differentiate between full penetration welds and partial welds securing the set-in nozzles to the drum. The membrane hoop stress (design stress) in the drums had a range of about 9 ton/in.^{2}, corresponding to 35 per cent of the U.T.S., and the average life of three tests on each of the weld details was 36,000 for partial penetration welds and 51,000 for full fusion welds.

Plainly, the strength reduction factor for both of these branch details is in excess of Kooistra's blanket factor of 4, because otherwise they would have been expected to survive 10^5 cycles. On the other hand, the branch details were unreinforced and therefore not in conformity with code requirements. Nevertheless, the performance of these unreinforced branches is quite remarkable and shows that the designs would have been quite adequate for many applications. Other tests were made on vessels which were identical in all respects except that the branches were fitted to protrude slightly inside the vessel, and a large increase in fatigue life resulted. For fillet-welded branches the average life of three specimens was 73,000 cycles and for branches welded with full penetration the life was 173,000 cycles, when tested under identical conditions.

Stress Systems

The type of stress concentration existing in pressure vessels varies between limits which have been recognised and described by the I.I.W. The first limiting case, denoted α-stressing, is where the high stresses are widespread and plastic deformation is possible because no support is available from surrounding material at lower stress. Extra thickness or a more favourable shape is required to limit the deformation. The other limiting case, ω-stressing, occurs where the stress concentration is sharply peaked in relation to the plate thickness, and full plasticity of a section, with ensuing large deformation, cannot take place.

The former case may be dealt with by means of relatively simple strength analyses. The latter case is important from the viewpoints of fatigue and stress-corrosion. Between the two there is an infinite variety of stress distributions calling for judgment and experience in the designer to ensure that each is adequately treated. Elastic analyses of these stress problems are of the greatest assistance and reference can be made to Carlson and McKean[8] for stresses in drumheads, and to reports of B.W.R.A.[9] for stresses at branch connections.

The latter reports show that the stress concentration at branches reinforced to the rules of the codes has a value of at least 2·5, and that this figure may be greater for

Photo: Power Gas Corp. Ltd.

Ninety-seven-ton mild-steel pressure vessel for the chemical industry, illustrating the complexity of external details. When code designed, stresses and failure are not predicted for each detail, reliance being placed in a high safety factor. In rational design each stress raiser must be considered as a source of potential failure. Prediction of failure leads to more economical but equally safe design.

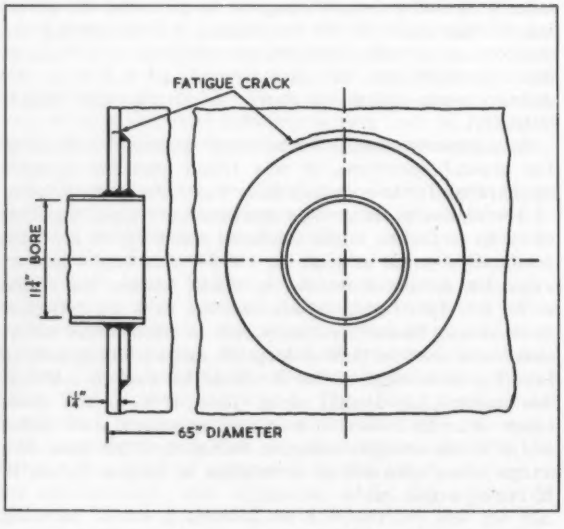


Fig. 2. Fatigue cracking around nozzle of steam accumulator.

Vessel, 74 ft. long, by Robert Watson & Co. (Constructional Engineers) Ltd., designed for an operating pressure of 337 p.s.i.g. at 100 deg. C.

vessels of larger diameter/thickness ratio than those tested, and for cases where the branch bore is greater relative to the drum bore. Since the peak stress at reinforced branches usually occurs as a hoop stress at the bore of the branch on a longitudinal section of the drum through the branch, it is not influenced to a great extent by notch effects such as those due to the use of partial penetration welds. The stress gradient is therefore determined by the size of the opening, the drum radius and thickness of drum plus reinforcement, and has a low value relative to that found at, say, small notches or the toes of fillet welds. The stress concentration can be expected to develop very nearly its full effect in fatigue failure under this condition, and therefore the strength reduction factor is likely to approach the stress concentration factor in value. The value of k_f for code reinforced nozzles is therefore 2·5, or greater, with reference to as-rolled plate, and when referred to ground specimens k_f becomes $2{\cdot}5 \times 1{\cdot}6 = 4$. Kooistra's proposed figure is realistic, therefore, and probably on the low side.

DESIGN CONSIDERATIONS—If a revised design procedure is to be used in which specific possibilities of failure are considered in order to make economies in materials, it is apparent that a closer assessment of the service conditions of each vessel must be made. It will no longer be possible to use a single tabulated design stress and apply this to vessels almost regardless of the duties the vessel is to perform, and regardless of the discontinuities of the cylindrical shell. Furthermore, it will be necessary to consider what margin of safety is desired in any given vessel, for each of the possible modes of failure.

At present, pressure vessels are required to withstand a proof hydrostatic pressure test to 1·5 × working pressure. If this practice were to continue, it would be necessary to design for this pressure on a basis of resisting excessive deformation. This would limit the nominal hoop stress at working pressure (for vessels designed to work at temperatures below the creep range) to two-thirds of the yield point, and thus prohibit the development of the full material potential. This limitation would be felt most severely in vessels having only negligible stress concentrations. Such a vessel might consist of a plain, unpierced, drum with hemispherical drumheads having central branch connections. In the absence of stress concentrations the vessel could work satisfactorily at pressures producing a hoop stress of say 90 per cent of the yield point, if there were no requirement for an initial over-pressure test.

The value of the hydrostatic test for vessels having low stress concentrations seems doubtful. For these it is merely a check on gross errors of design or fabrication. However, for vessels having branch connections, relatively shallow drumheads and other stress-raising discontinuities, the situation is different. The benefit to fatigue resistance of an initial over-loading has been demonstrated for some structures, and the hydrostatic test may have a similar influence in pressure vessels. Additionally, the over-pressuring ensures dimensional stability in service operation, since any tendency to deform plastically will be absorbed to a large extent during the test. It appears, therefore, that the hydrostatic test may be useful in directions rather different from those of its original purpose, and its application might be moderated in relation to the design of each vessel and the possible benefits of over-pressuring.

Another feature of code requirements which has its origin in the very different circumstances of early pressure vessel design is the habit of assigning a joint efficiency to a welded seam. It is well known that welds are currently made in steel with strengths equal to the parent plate, and the fatigue resistance of these welds can be indistinguishable from those of the unwelded material[3] when the mill scale is not removed. Joint efficiencies are not required, therefore, on the grounds of strength. Penalties in joint efficiency for vessels which are not stress-relieved, or for which the welds are not inspected for flaws by radiography, are likewise indefensible, since no correction to the joint efficiency can compensate for the presence of a residual stress system, or hidden flaw, with reference to the possibility of a brittle fracture.

In conclusion, it appears that while we have sufficient knowledge now to incorporate new rational methods in code design, there remain many difficulties of interpretation of failure phenomena, observed in simple specimens, in terms of the far more complex conditions in pressure vessels. Our knowledge of stress distributions must be extended to cover a wider range of shapes and details and correlations established between these stress systems and the failures observed in tests of full-size vessels.

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NEW GROUP OF SUPERCONDUCTORS

URANIUM, the nuclear fuel that made possible large-scale useful atomic power, has yielded a new "family" of chemical compounds which belong to a group of substances called superconductors.

Superconductors are characterised by the remarkable ability of permitting an electric current, once started in them, to flow in undiminished strength for ever. Long a scientific curiosity, they are now beginning to find practical application in midget computers of the type useful for the airborne control of rockets, missiles and other space vehicles.

The new superconductors were discovered by Dr. B. S. Chandrasekhar, physicist in the metallurgy department of the Westinghouse research laboratories in the U.S.A., and Dr. J. K. Hulm, manager of the laboratories' solid-state physics department.

The superconductors were found during research on the electrical resistance of uranium alloys at temperatures less than one degree above absolute zero—the lowest possible temperature in the universe—and 459 degrees below zero on the Fahrenheit scale of measurement.

The new superconductors, four in all, include the first ever known to contain manganese and iron, two elements that always have been considered alien to the existence of superconductivity. All are known as "intermetallic compounds" and are alloys of uranium and one other metal.

Dr. Hulm has described superconductivity as being among the most startling phenomena in all physical science. It occurs in various metals and alloys at very low temperatures. For reasons that are not now well understood, the electrical resistance of these materials suddenly drops to about one-millionth of one-billionth of its normal value. Electric currents flow in them undiminished.

The measurements of electrical resistance were made on uranium-molybdenum and uranium-columbium alloys that had been stabilised in crystal structure by heating to 1,650 deg. F. for twenty-four hours and quenching in water.

The alloys showed surprising temperature-resistance behaviour. Contrary to all known alloys, their electrical resistance became progressively larger as the temperature was decreased all the way down to one or two degrees above absolute zero, at which temperatures they became superconductors. The superconductivity was regarded as surprising in view of the rise in electrical resistance preceding it. Correlation of the superconducting and resistivity data has thrown new light on the electronic structure of the atoms making up the alloys.

To examine more closely the superconducting behaviour of uranium alloys, a study was then made of a group of "intermetallic compounds". Such compounds form when uranium is chemically combined with such metals as aluminium, manganese, iron, cobalt and nickel. It was from these studies that the new superconductors emerged.

Four undiscovered superconductors were found among the intermetallic compounds containing cobalt, manganese and iron. Of special interest was the fact that two of them are the first superconducting compounds ever known to contain manganese and iron. Previously, the presence of these two elements has been regarded as disastrous to the superconducting state. However, these new superconductors are now not only a reality, but may be among the most useful in superconductor research.

PRECISION ENGINEERING WITH PERSPEX

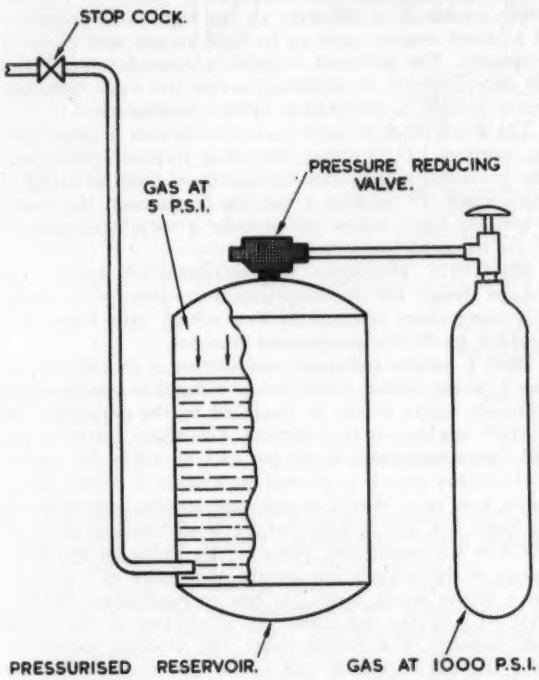
POLYMETHYL methacrylate sheets and rods have provided the engineer with a precision material having some unique and valuable properties. Produced in the U.K. by I.C.I. Ltd. under the name of Perspex, by which it is more generally known, the resin is thermoplastic, colourless and little affected by prolonged outdoor exposure, even under tropical conditions.

An interesting example of the kind of component which can be produced from this material is the conductimetric cell (shown here) which was made for G.E.C. by R. O. Harris & Co. Ltd. Perspex was chosen in this instance for its insulation properties, strength, resistance to chemicals and transparency. The body of the cell was produced from tubing, bored to receive the end plates. The helical gear, used as a path for the gas bubbles, was machined from a solid block of Perspex. A core through the helix is of the same material, carrying two wires for attachment to electrodes.

The operation of the cell, used for the determination of carbon in metals, consists of heating the sample in oxygen until the carbon in the sample is converted into carbon dioxide. The carbon dioxide is then dissolved in a solution of caustic soda or barium hydroxide and the change in conductivity of the solution is measured.

designer's notebook

A Two-stage Pressure Reducing Valve

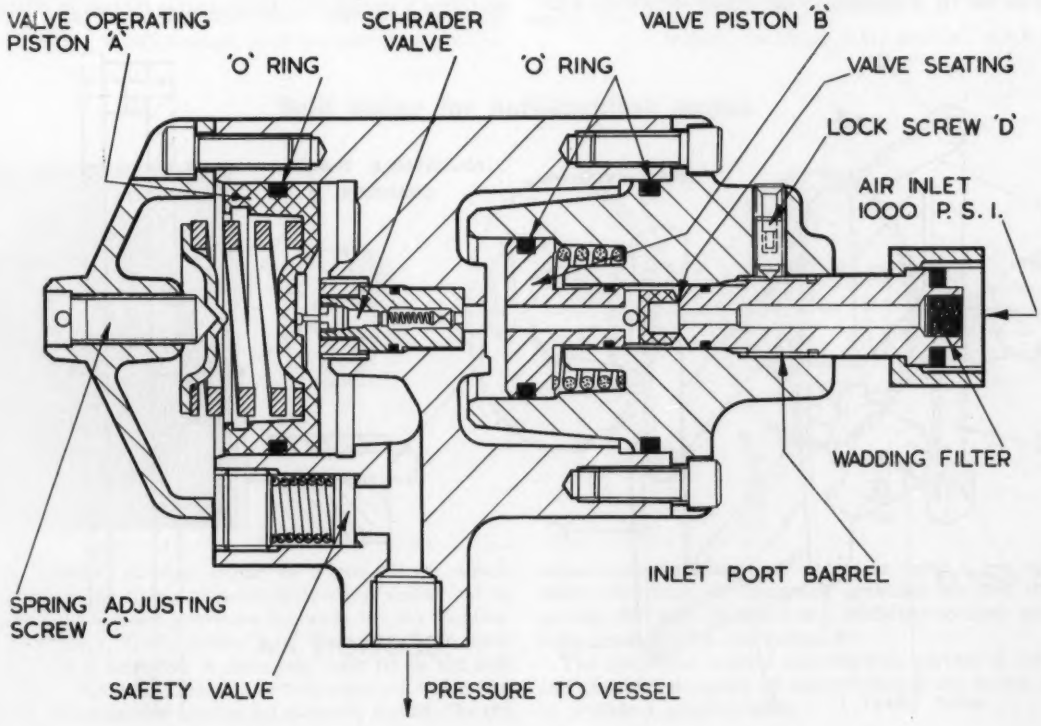


TO eliminate the use of a manual lift pump for drawing liquid from a reservoir at a lower level and provide, instead, means whereby the liquid could be drawn off merely by the opening of a stop cock, it was decided to pressurise the reservoir with a cylinder of CO_2. As the reservoirs were soon exhausted of their contents, the pressure in the CO_2 cylinder, which could be attached in turn to a number of such reservoirs, would gradually fall from 1,000 p.s.i. when supplied to around 20 p.s.i. To provide the necessary lift required, a pressure in the reservoir of around 5 p.s.i. had to be maintained.

The pressure-reducing valve to solve this problem, developed by Alumasc Ltd. and for which a patent application has been made, employs two spring-loaded pistons A and B and a Schrader air valve as used in a motor tyre. The working principles of the two-stage valve are illustrated below.

When pressure in the liquid reservoir falls, the larger piston A moves to the right under spring pressure and operates the plunger of the Schrader valve. Reduction in pressure on the left-hand side of the piston B, caused by opening this valve, causes it to move to the left under spring pressure, and by so doing admit air at high pressure from the cylinder through cross-drilled holes in the plunger portion of the smaller piston, the end of which, fitted with a plastic seating, abuts against the entry port. When the required pressure in the reservoir has been attained, pressure against the right-hand side of the piston A moves it to the left and allows the Schrader valve to close.

An adjustable spring-loaded safety valve is provided.



Sinusoidal Movement Without Sliding Pairs

IT is well known that the ordinary crank mechanism common in piston engines does not produce a pure sinusoidal motion. When the crank pin rotates uniformly, the cross-slide or piston performs a reciprocating motion which differs from the sinusoidal by the superposition of an appreciable second harmonic and smaller higher harmonics. The magnitude of the second and higher harmonics depends on the ratio of the crank arm and the connecting rod length. The larger the ratio, the greater the deviation from pure sinusoidal motion.

Sometimes it is desirable to produce by mechanical means a purely sinusoidal reciprocating motion. This need arises in test rigs, vibrating tables and other applications where a single frequency in the reciprocating motion is functionally an essential feature. The so-called "Scotch yoke" is a mechanism wherein a reciprocating slider moves sinusoidally when the crank pin rotates uniformly about the centre of the crankshaft.

PURPOSE OF HARMONIC EXCITER—The Scotch yoke mechanism has two sliding pairs. A harmonic exciter linkage which avoids sliding pairs was incorporated as a harmonic input unit in a test rig designed and built by Servotec Ltd. to the specification of Ardleigh Engineering Ltd. The harmonic input converts the uniform rotation of a small electrically-driven variable-speed hydraulic transmission unit into a pure sinusoidal reciprocating motion.

This straight-line reciprocating motion is, in turn, converted into a purely sinusoidal variation of an angle, namely the angle of the control lever of a large hydraulic motor (Vickers VSG) supplied by an electrically-driven Vickers VSG pump unit. A sinusoidal variation of the control lever angle causes sinusoidal torque fluctuations and so constitutes a pure harmonic torque input applied to the shaft, which simulates a diesel engine. The governor tested on the rig is coupled to the engine simulating shaft. Thus the rig is adapted to test the open-loop harmonic response of a governor.

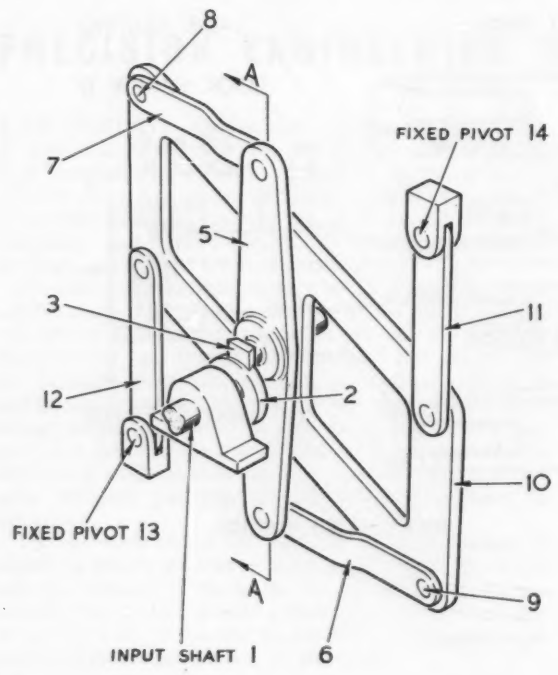
The rig is provided with a number of additional features which enable it to simulate all the significant properties of a diesel engine, such as its load torque and damping properties. The governor actuates a control valve. When the control valve is connected across the main hydraulic motor circuit, a closed-loop system is created.

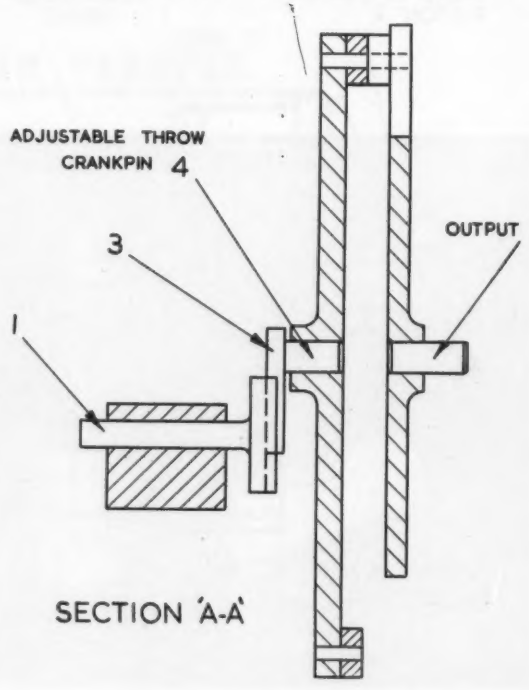
The importance of pure harmonic motion is clear from the purpose of recording harmonic response behaviour. The harmonic transformer linkage, apart from its variable-speed input (to produce a variable frequency), also needs a variable crank throw (to produce a variable amplitude of the harmonic output).

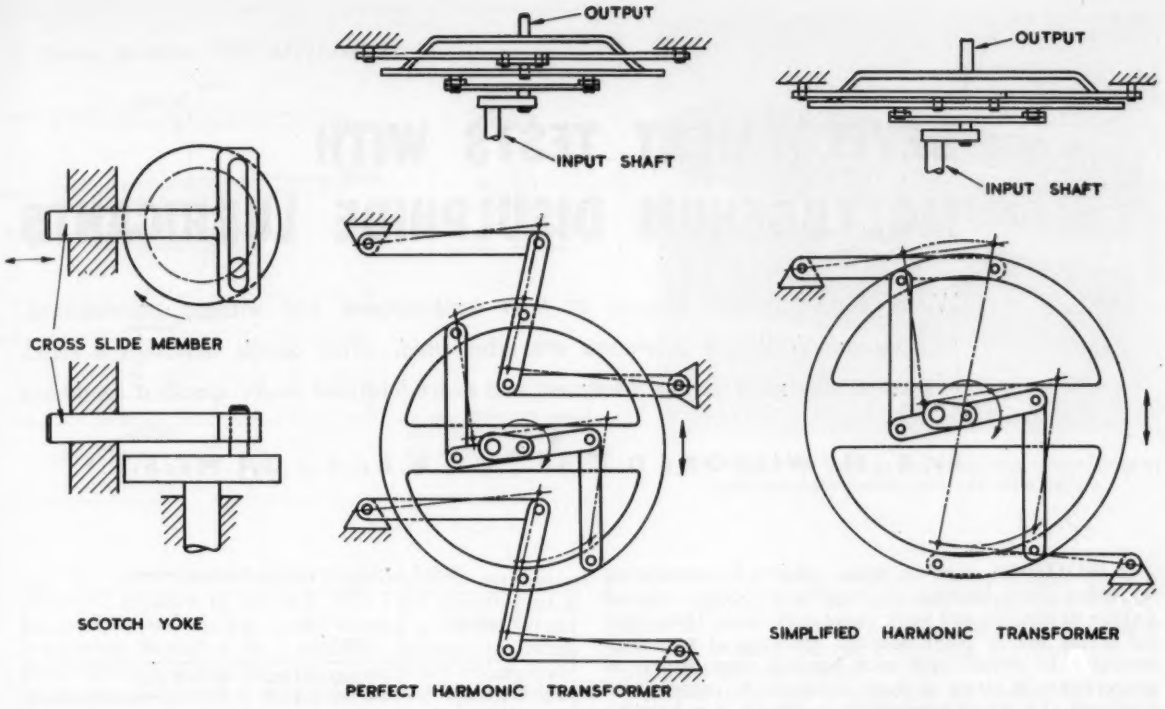
SIMPLIFIED HARMONIC TRANSFORMER—Basically, the linkage design for this application consists of a Scotch yoke mechanism wherein the two sliding pairs have been replaced by Watt's straight-line motions.

Shaft 1 rotates uniformly and carries at its extremity a disc 2, along whose centre line a slider 3 is dovetailed in a groove, where it can be displaced by the adjustment of a screw mechanism (not shown). The slider carries a pin which thus becomes a crank pin with an adjustable throw.

The crank pin 4 is pivoted in a lever 5 which is the centre link of a Watt's straight-line motion composed of the links 5, 6 and 7. This linkage is anchored at pivots 8 and 9 in the centre link plate 10. By virtue of the kinematics of the straight-line motion, the centre of the crank pin 4 moves along a straight line in relation to the link plate 10, just like the crank pin in relation to the cross-slide member of a Scotch yoke. The absolute motion of the crank pin is circular and so the link plate 10, like the cross-slide of the Scotch yoke, is forced to move transversely. In doing so, the centre point of the link plate performs a straight-line reciprocating motion in relation to







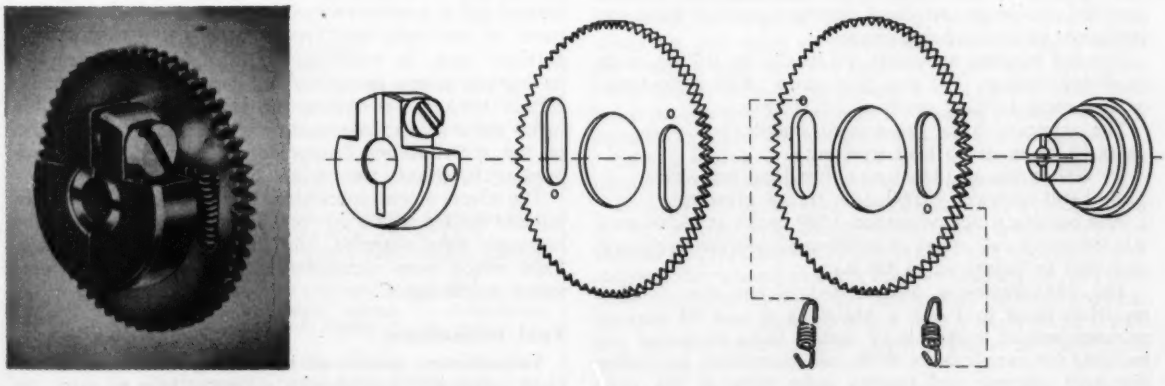
the ground, because the link plate 10, together with the links 11 and 12, is another straight-line motion linkage anchored to the ground at the pivots 13 and 14.

PERFECT HARMONIC TRANSFORMER—The centre point of the link plate 10 thus performs nearly the same motion as the cross-slide of a Scotch yoke. Thus the linkage as shown produces a nearly sinusoidal motion of a single point. In some applications this is sufficient, in others it is necessary to produce sinusoidal reciprocating translation along a straight line of a body which should be constrained against rotation. If so, the centre link plate, instead of forming part of another Watt's linkage, joins the two "straight-line points" of *two* staggered Watt's linkages, both anchored.

In this case, the centre link plate becomes the reciprocating body constrained against rotation. Apart from providing the additional constraint, this more complex linkage is a perfect embodiment of the Scotch yoke principle, whilst the simplified linkage is an approximate embodiment. It is approximate because the centre link plate 10 itself slightly rotates during its motion and so changes the direction in space of the straight line fixed to itself along which the crank pin centre 4 reciprocates relatively to the centre link plate.

J. S. Shapiro, Dipl.Eng., A.M.I.Mech.E., A.F.R.Ae.S.

Split Collar for Anti-Backlash Device



THE Bendix Autosyn collar is a component which facilitates the fixing of gears to synchro shafts and at the same time enables provision be made for the elimination of backlash. The exploded view illustrates the manner in which this is achieved. A three-step bush forms the hub of the gear. To the larger of the two steps on which the gears are mounted one gear is permanently staked. On the second step the other gear is free to move a few degrees within the limit of constraint provided by two tension springs, the ends of which are anchored to each gear by holes provided for the purpose.

The split collar is fitted over the split portion of the bush and provides a means of compressing it on to the shaft, to provide a positive drive.

DEVELOPMENT TESTS WITH MOLYBDENUM DISULPHIDE LUBRICANTS

Where bearings must operate at high temperatures and without maintenance, molybdenum disulphide lubricants are often used. This article describes a series of tests to determine surface treatment and exact lubricant under specified conditions

by S. M. WILSON, D.C.Ae., A.F.R.Ae.S., G.I.Mech.E.*

CONDITIONS exist in many spheres of engineering today where bearings are required to occupy as small a space as possible and work under high loads. These have led to the use of plain bearings operating at very high pressures. In certain cases such bearings must operate at temperatures in excess of those withstood by conventional lubricants and, where accessibility is difficult, it is desirable that bearings be given initial lubrication, and then run without further attention.

A specific design requirement was for a plain bearing in two given high-tensile steel materials, to operate at 45,000 p.s.i. at 250 deg. C. The motion was oscillatory, through ±45 deg. at a speed of 10 cycles/min. with an arbitrary target life, or endurance, set at 1,000 cycles. Development tests were initiated to establish a surface treatment and lubricant to meet this requirement and the article describes the experimental investigation and results thus obtained.

A particular set of test conditions, representing the most severe likely in service, was chosen and a total of 165 journal specimens in five steel materials were tested, the majority at room temperatures. Ten surface treatments and fourteen lubricants were tried, from which were established a lubricant and surface treatment suitable for use in the specified conditions, details of clearance, surface finish and coefficient of friction being given.

The test bearing, nominally 1·6 in. dia. by 0·75 in. wide, oscillated through ±45 deg. at a speed of 10 cycles/min., or at a mean rubbing speed of 2·1 ft./min.

The arbitrary target life was to include:

(a) 30 cycles at no load (run in);

(b) 200 cycles at 15,000 p.s.i. (working pressure);

(c) 1,000 cycles at 45,000 p.s.i. (proof pressure).

Any bearing which withstood 3,000 cycles at 45,000 p.s.i. was tested for two cycles at 60,000 p.s.i. (ultimate pressure) and then to failure at 45,000 p.s.i.

The 165 specimens were tested in the five different materials listed in Table 1. Materials II and III were of primary interest, materials IV and V being incidental and included for completeness. With nine exceptions, not further discussed, journal and bearing pairs were of the same material.

Since materials II and III were in short supply at the start of the programme, much of the basic work was covered using material I, some eighty-two specimens being tested in this material.

* *Structures and mechanical test section, engineering laboratories, Bristol Aircraft Ltd.*

TABLE 1. Types of bearing material tested

Material	U.T.S. (p.s.i.)	Description
I S.99	179,000–201,000	Nickel steel
II DTD.551 (derivative)	246,500–269,000	3% chrome molybdenum vanadium steel
III FV.448 (derivative)	156,500–190,500	12% chrome steel
IV S.82	190,500 (min.)	Case hardening steel (not case hardened in these tests)
V DTD.551 (derivative)	201,000–224,000	3% chrome molybdenum vanadium steel

Early tests demonstrated that a surface treatment of the bearing was necessary to provide a key to hold the lubricant, and each of the following ten treatments was investigated: vapour blast, electric spark etch, nickel plate, chrome plate, sulphur-rich layer, manganese phosphate, iron phosphate, oxalate treatment, phosphoric nitric acid pickle, and caustic nitrate.

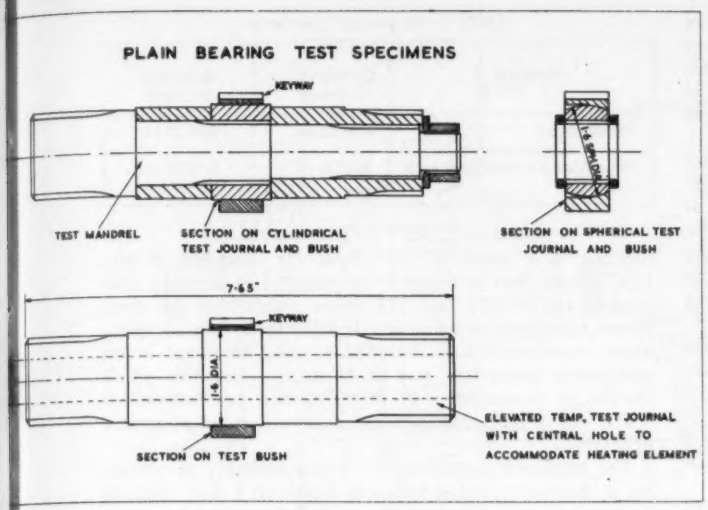
Conventional grease lubricants were known to be unsatisfactory at the pressure and temperature being considered and a potential solution appeared to lie with lubricants of the solid-film type. These are basically solid particles such as molybdenum disulphide and graphite having lubricating properties and generally combined with certain binders. To obviate the risk of dealing with too many variables, the investigation was confined to lubricants of the molybdenum disulphide type and fourteen proprietary lubricants were tried.

The effects of post-lubrication treatment such as burnishing and buffing with a felt bob after the application of the lubricant were observed, and these lubricants and treatment which were successful at room temperature were tested at 250 deg. C.

Test Procedure

Two different designs of journal were used, the first a plain cylindrical journal with a central hole to carry the heating element, and used for tests at elevated temperatures, and the second design was a built-up mandrel type. This mandrel was utilised for spherical bearing tests, the bearing portion being interchangable.

The test rig is shown in Fig. 3 with a sectional drawing of the loading arrangement, and it will be seen that it comprises a drive to the test shaft, a hydraulic jack to load


PLAIN BEARING TEST SPECIMENS
KEYWAY
TEST MANDREL
SECTION ON CYLINDRICAL TEST JOURNAL AND BUSH
SECTION ON SPHERICAL TEST JOURNAL AND BUSH
7·65"
KEYWAY
1·6 DIA.
SECTION ON TEST BUSH
ELEVATED TEMP. TEST JOURNAL WITH CENTRAL HOLE TO ACCOMMODATE HEATING ELEMENT

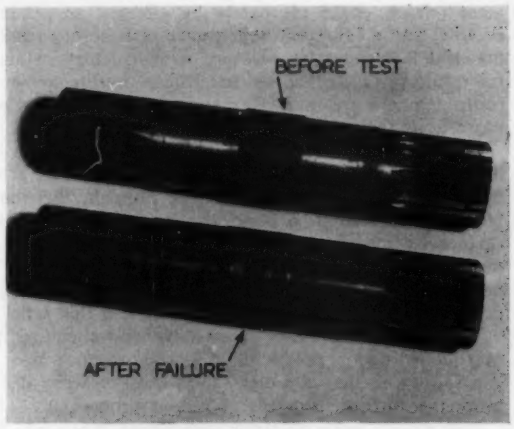


Fig. 1. *Left*—Plain bearing test specimens. *Above*—Typical test specimens before test and after failure.

the test shaft and a system supplying and measuring hydraulic pressure to the jack. The drive consisted of a 4-h.p. 700-r.p.m. electric motor driving a variable crank mechanism through a 70:1 reduction gearbox, the crank mechanism converting the drive from rotary action to an oscillatory movement of ± 45 deg. The test shaft is driven from the crank mechanism through a removable shaft necked and strain-gauged to facilitate measurement of driving torque.

The test shaft is supported in pairs of ball races and loaded by means of the hydraulic jack through a guide rod into which the test bush is keyed. The rig provides for easy assembly and removal of the test shaft and bush. The hydraulic pressure system comprised an electric motor driving a low delivery rate, swash-plate type hydraulic pump which supplied oil to a pressure controller of the deadweight type through an accumulator and thence to the loading jack.

Measurements of driving torque were made by means of the electrical wire resistance strain gauges using a camera recorder, and the measured torque included that needed to drive the support races. The latter was calculated and allowed for in computing the coefficient of friction for the test bearing.

For tests at elevated temperatures the bearing was heated by means of a 1·5-kW. inconel-sheathed element fitted in the core of the test shaft. Input to the element was controlled by means of a 20-amp. voltage regulator and the desired temperature maintained by a temperature indicator and controller of the on-off type. Bearing temperature was measured using copper-constantan thermocouples.

ALL SPECIMENS—Prior to treatment the surface finish of the bearing was measured, together with the "as-ground" clearance. Following surface treatment (e.g., manganese phosphate) the lubricant was applied, and in some cases excess lubricant was removed by buffing to allow assembly of the bearing. Generally, molybdenum disulphide in a mineral oil (lubricant G, Table 2) was used as an assembly lubricant. Material II, the 12 per cent chromium steel, could not be manganese phosphated because of its high alloy content, and this problem was overcome by iron plating prior to phosphating.

ROOM TEMPERATURE SPECIMENS—Each bearing was tested for 30 cycles at no load to run it in. It was then tested for 200 cycles at 15,000 p.s.i., representing a working pressure, and thence to failure at 45,000 p.s.i. in batches of 100 cycles initially, increasing to 300 cycles. After each batch the test was stopped and the bearing cooled for a few minutes to allow friction-generated heat to dissipate.

During testing, a supply of cold air was continuously played on the specimen for cooling purposes.

ELEVATED TEMPERATURE SPECIMENS—Thirty cycles "run in" at no load were completed at room temperature, the bearing then heated to 230-240 deg. C. and cycling recommenced, the bearing being loaded to 15,000 p.s.i., friction-generated heat raising the temperature to the required 250 deg. C. Two hundred cycles were completed at 15,000 p.s.i. and the specimen then cycled to failure at 45,000 p.s.i. at 250 deg. C.

TABLE 2. Types of molybdenum disulphide lubricant

Lubricant	Constituents
A	Micro-fine particles of MoS_2.
B	MoS_2 in a silicon grease.
C	MoS_2 in dextrose. Curing time, 1 hr. at 250°C.
D	MoS_2 in a freon-type propellent.
E	MoS_2 in ethyl alcohol.
F	MoS_2 in water.
G	MoS_2 in a mineral oil.
H	MoS_2 in a resin base diluted in toluene. Curing time, 1½ hr. at 220°C.
I	MoS_2 in alcohol with a phenolic thermosetting resin binder. Curing time, ¾ hr at 210°C.
J	MoS_2 in n-butanol with a resin binder. Curing time, ½ hr. at 180°C.
K	MoS_2+graphite (90 per cent MoS_2, 10 per cent graphite) by weight approx. in a modified thermosetting resin binder. Curing time, 1 hr. at 190°C.
L	MoS_2+graphite (micron sized) in a modified thermosetting resin binder. Curing time, 1 hr. at 190°C.
M	Micro-fine particles of MoS_2 and synthetic graphite in silicones with a high-temperature phenolic thermosetting resin binder. Curing time, 2 hr. at 285°C.
N	MoS_2+graphite+lubricative pigments in a phenolic or vinyl thermosetting resin binder. Curing time, 4 hr. at 177°C.

Form of Investigation

Although production bearings were to be spherical, most of the test specimens were of the cylindrical type for cheapness. Check tests were made on spherical bearings at room temperature, however, using the established process.

It was decided to attempt to establish a surface treat-

ment (which could ultimately be effected as production routine) and a lubricant which gave satisfactory results on material I at room temperature, a satisfactory or successful result being defined as one where the life achieved at room temperature was of the order of 1,000 cycles, or more at 45,000 p.s.i.

Early tests, where attempts were made to burnish either lubricants A, B, C or D (Table 2) into the "as ground" bearing surface, were failures. To burnish, the shaft or bush was rotated in a lathe and pressure applied to the surface by means of a roller tool mounted on the lathe tool-post. It became obvious that some sort of "key" was necessary to hold the lubricant at the proposed bearing pressures. These means are listed earlier in this article.

The most successful of mechanical and chemical means of roughening or producing a porous surface was manganese phosphate, although good results were obtained using the surface sulphur-enrichment process.

Best results were obtained with MoS_2 lubricants which contained a resin binder. Lubricants C and H had been tried at this stage, the latter being preferred.

Having established a suitable process, it was applied to the material II, the Cr-Mo-Va steel, and tested at room and an elevated temperature of 250 deg. C. When this stage was completed, the process was tested on the chrome steel. Supplementary tests on materials IV and V were included for completeness.

Results obtained from this point onward have been collectively summarised in Table 4, the results of the successful tests being discussed hereafter. The basic tests served to establish a point from which development tests could begin.

Bearing Endurance

Comparisons of bearing endurances were made in terms of cycles to failure at 45,000 p.s.i. (see Table 4). Appreciable scatter of results existed, the worst being the order of 10 to 1, and conclusions were drawn therefore in terms of trend rather than net results.

CYLINDRICAL BEARINGS AT ROOM TEMPERATURE—Mean lives of the order of 3,200 cycles were obtained on specimens in material II using either lubricant H or I, both on a manganese phosphate pretreatment. The mean life obtained on material IV using lubricant H was 2,870 cycles, only slightly less than that on material I. The life was reduced to a mean of 759 cycles for lubricant H and 1,147 cycles for lubricant I on material II similary pretreated, and to 611 and 773 cycles respectively on iron-plated specimens in material III. The mean life of specimens manufactured in material V using lubricant H on manganese phosphate was 1,242 cycles, and this result should be compared with that obtained on material II which was of the same chemical composition but of greater strength.

Fig. 2. Test specimen being removed from test rig for inspection.

TABLE 3. "As-ground" clearances

Materials	Cylindrical bearings	Spherical bearings
Phosphated	0·0015 in.	0·0020 in.
Iron-plated and phosphated	0·0030 in.	0·0035 in.

The lubricant manufacturers found difficulty in obtaining a satisfactory shelf life with lubricant I and replaced it with lubricant J. Although only single specimens were tested with each material using the new lubricant, lives of 4,380 cycles and 3,100 cycles were obtained in material II and III respectively on a manganese phosphate pretreatment. Allowing for scatter of results, this was the most promising room temperature result. Three further lubricants, K, L and M, of American origin were tried giving lives of 1,301, 700 and 1,300 cycles on material II manganese phosphated, another American lubricant, N, being unsuccessful. These lives were of the same order as those obtained with British lubricants.

The sulphur-enrichment pretreatment with lubricant H gave lives of 2,282 and 663 cycles on materials II and III respectively, and with lubricant I a life of 8,414 cycles was obtained on material II. This pretreatment was not investigated further, however, as it could not be applied to material II, this material having a tempering temperature lower than that required for the sulphur-enrichment process. Also, this pretreatment was associated with high and erratic coefficients of friction.

SPHERICAL BEARINGS AT ROOM TEMPERATURE—The mean life obtained from spherical bearings in material I phosphated and treated with lubricant H was 821 cycles, or approximately a quarter of that obtained from similarly-treated cylindrical bearings. Bearings in material II treated with lubricant J gave a mean life of 1,197 cycles, or approximately a quarter the life of similarly-treated cylindrical bearings. A bearing in material III, iron-plated, phosphated and treated with lubricant J, gave a life of 1,207 cycles, or just over a third of the life obtained from a cylindrical bearing.

The reduced lives obtained on spherical bearings were probably caused by higher local bearing pressures, due to line rather than surface contact—a result of the less accurate machining possible on a spherical shape. The bearings tested were of the type having a rebate to facilitate assembly, and a diameter through the rebate was at right angles to the applied load. The rebate should be carefully radiused to avoid pick-up at this point. Split bushes might have advantages over the rebated type where it is possible to use them.

ELEVATED TEMPERATURE (250 DEG. C.) CYLINDRICAL SPECIMENS—The best lubricants at 250 deg. C. were I and J, and the mean life of specimens in material II phosphated and lubricated with lubricant I was 473 cycles compared with 1,147 cycles at room temperature, or approximately half the room temperature life. Lubricant J gave a life of 800 cycles on a single specimen in the same material compared with 4,380 cycles at room temperature, also on a single specimen.

In contrast, lubricant I on material II iron-plated and

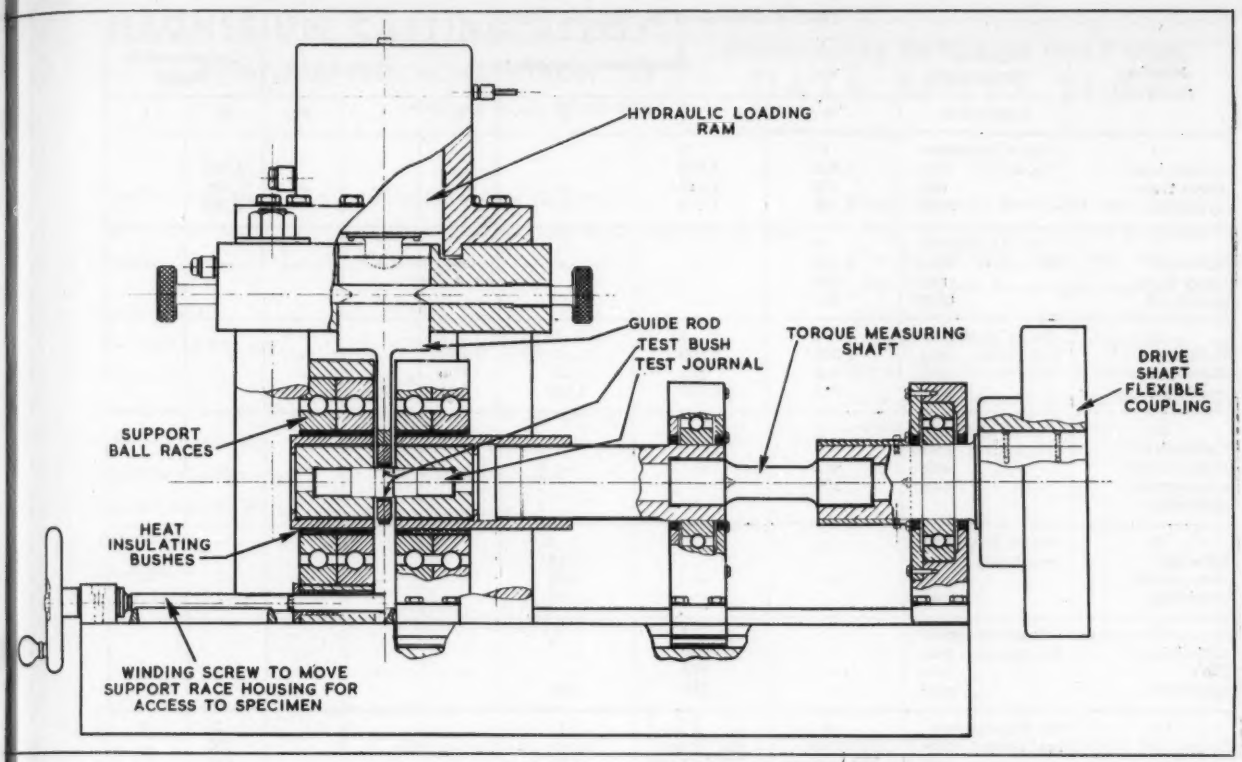


Fig. 3. Loading rig of the type used in the tests described in this article.

phosphated gave a mean life of 3,417 cycles compared with 773 cycles at room temperature, although in the former a different iron solution was used which no doubt improved the life considerably. Lubricant J gave a life of 1,500 cycles on a single specimen in material II compared with 3,100 cycles at room temperature, the new iron solution being used in both these tests.

Observations

DESCRIPTION OF FAILURE—The bearing was judged to have failed when the surface became badly scored. This amounted virtually to seizure, but due to the high driving torque provided by the test machine no case of actual seizure occurred.

Imminent failure caused a rise in torque which was indicated by a meter incorporated in the camera recorder, and also, occasionally, by loud squeaking from the specimen. The test was then stopped, and if the torque increased by 30 per cent or more over the mean value the bearing was stripped and examined. In these circumstances, and invariably if the torque had shown an increase greater than 40 per cent, scoring was apparent. The build up of torque leading to failure was fairly rapid, and occurred over approximately the last 60 cycles of the life in all materials.

APPLICATION OF LUBRICANTS—The method of applying the lubricant is important. Dipping was used initially, but this method gave an uneven layer of lubricant with globules of hard MoS_2 and resin after curing. This is undesirable because excess lubricant had to be buffed or burnished off with the risk of removing too much. Spraying was then adopted and found satisfactory, provided care was taken to apply the lubricant evenly. To obviate the need to provide special spraying facilities for production, a method of applying the lubricant by rolling on with an impregnated felt pad was successfully used.

BURNISHING AND BUFFING—Burnishing, used in the early part of the programme to "push" the lubricant into the surface, and later to smooth out uneven layers of lubricant resulting from dipping, is not recommended as the tendency was to remove lubricant by flaking.

Buffing by holding the bearing against a rotating soft felt bob was permissible, provided it was done lightly and carefully and used only to remove *excess lubricant*, thus allowing mating parts to be assembled. Using the minimum clearances recommended below, even light buffing should be unnecessary, provided a smooth film of lubricant is obtained.

As a result of experiments, the recommended "as-ground" clearances were found to be as given in Table 3. All bearing surfaces were ground finished, the measured finish being in the range of 3½ micro-in. to 30 micro-in. There was no relationship between surface finish and bearing life in this range.

COEFFICIENT OF FRICTION—The measured mean coefficients of friction generally lay in the range 0·05 to 0·10. Using lubricant H on a manganese phosphated surface at room temperature, the mean coefficient of friction obtained was of the order of 0·1 on all materials. No value is available for lubricant I on material II at room temperature, but at 250 deg. C. the mean value was 0·085. Corresponding values on material III were 0·065 and 0·05 at room and elevated temperatures respectively. Likewise, lubricant J on material II gave values of 0·074 and 0·054 at room temperature and 250 deg. C. respectively, while on material III values of 0·063 and 0·067 were obtained.

Conclusions

(1) The best lubricant at room temperature was lubricant J, although only one specimen was tested in material II and one in material III.

Other lubricants which gave satisfactory results at room temperatures were lubricants H, I (now obsolete), K, L and M.

TABLE 4. Summary of successful test results

Bearing material	Surface treatment	Manganese phosphate						Sulphur-rich layer	
	Lubricant	H	I	J	K	L	M	H	I
I Cylindrical room temp. specimens	*No. of specimens*	11	2					2	
	No. cycles max.	7,000	3,858					3,080	
	min.	750	2,694	—	—	—	—	1,484	—
	mean	3,158	3,276					2,282	
I Spherical room temp. specimens	*No. of specimens*	6							
	No. cycles: max.	1,555	—	—	—	—	—	—	—
	min.	500							
	mean	821							
II Cylindrical room temp. specimens	*No. of specimens*	5	3	1	2	1	1		
	No. cycles: max.	1,000	2,500	—	1,603	—	—		
	min.	458	275	—	1,000	—	—	—	—
	mean	759	1,147	4,380	1,301	710	1,300		
II Cylindrical room temp. cross-grain specimens	*No. of specimens*	2							
	No. cycles: max.	600							
	min.	412	—	—	—	—	—	—	—
	mean	506							
II Spherical room temp. specimens	*No. of specimens*			3					
	No. cycles: max.			1,766					
	min.	—	—	895	—	—	—	—	—
	mean			1,197					
II Cylindrical 250°C. specimens	*No. of specimens*		7	1					
	No. cycles: max.		700	—					
	min.	—	190	—	—	—	—	—	—
	mean		473	800					
III Cylindrical room temp. specimens	*No. of specimens*	4	3	1				2	1
	No. cycles: max.	1,037 iron-plated	1,060 iron-plated					700	—
	min.	300 iron-plated	330 iron-plated	3,100 iron-plated	—	—	—	627	—
	mean	611 iron-plated	773 iron-plated					663	8,414
III Spherical room temp. specimens	*No. of specimens*			3					
	No. cycles: max.			1,500 iron-plated					
	min.	—	—	1,018 iron-plated	—	—	—	—	—
	mean			1,207 iron-plated					
III Cylindrical 250°C. specimens	*No. of specimens*		3	1					
	No. cycles: max.		4,000 iron-plated	—					
	min.	—	3,000 iron-plated	—	—	—	—	—	—
	mean		3,417 iron-plated	1,500 iron-plated					
IV Cylindrical room temp. specimens	*No. of specimens*	2							
	No. cycles: max.	3,696							
	min.	2,045	—	—	—	—	—	—	—
	mean	2,870							
V Cylindrical room temp. specimens	*No. of specimens*	2							
	No. cycles: max.	1,500							
	min.	985	—	—	—	—	—	—	—
	mean	1,242							

NOTE: The "No. cycles" is the number of cycles to failure at 45,000 p.s.i.

(2) The best lubricant at 250 deg. C. was lubricant J, although again only one specimen in materials II and III was tested.

(3) The surface treatment plays a major part in the dry lubrication of plain bearings, manganese phosphate surface treatment giving the best results.

(4) The quality of the phosphate obtained affects the life in the sense that the poorer the phosphate the less the life. When the alloy content of the steel exceeds a certain limit the quality of the phosphate is reduced; in fact, material III would not phosphate at all. In the latter case plating with iron prior to phosphating provided a solution, and plating might be used on steels which phosphate poorly. Due to phosphate quality, materials I and IV gave considerably longer lives than materials II and III.

(5) The life obtained on a spherical bearing at room temperatures was of the order of one-quarter that obtained on a similarly-treated cylindrical bearing.

(6) The life obtained on a cylindrical bearing at 250 deg. C. was of the order of half that obtained at room temperature.

(7) Burnishing the lubricated bearing is undesirable. Buffing, although possibly necessary in some applications, is generally undesirable.

(8) Minimum "as-ground" clearances of 0·0015 in. for cylindrical bearings and 0·0020 in. for spherical bearings are recommended and these clearances should be increased by 0·0015 in. when iron plating is used.

(9) Surface finish in the range tested (3½ micro-in. to 30 micro-in.) was found to have no effect on bearing life.

(10) Mean coefficients of friction lay in the range of 0·05 to 0·10.

The author thanks Bristol Aircraft Ltd., for permission to publish this article, and the personnel of the engineering and chemistry laboratories who carried out the laboratory work.

MAGNESIUM CASTING ALLOY

HEAT-TREATED — ELEKTRON TZ6

(Fulfilling draft spec. DTD.000 M.40)

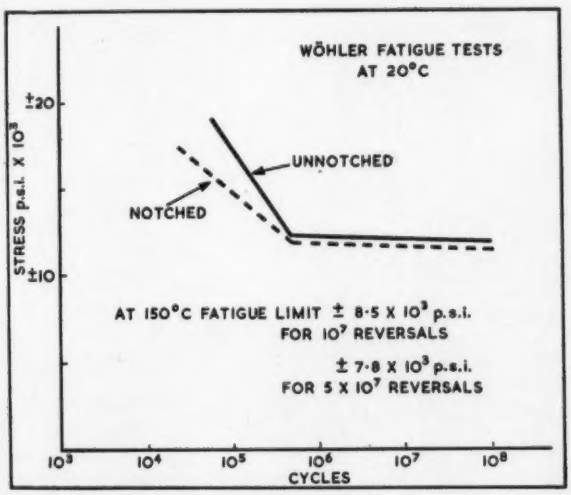
Engineering Materials and Design
DATA SHEET No. 7

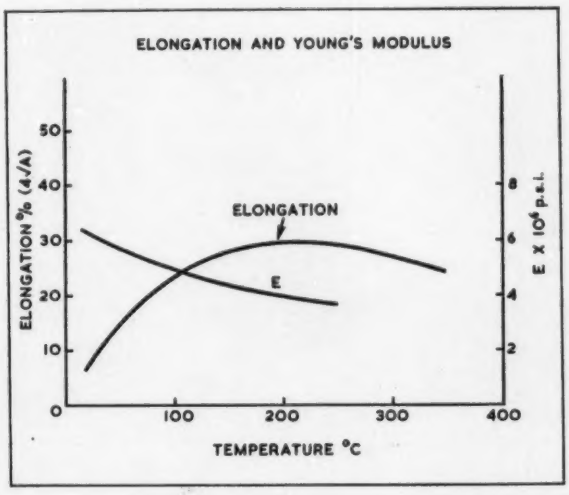
Typical Composition	5·5% Zn; 1·8% Th; 0·7% Zr.
Ageing Treatment	2 hr. at 330°C., cool in air plus 12 hr. at 180°C.
Density	1·87 gm./cm.^{3} 0·0675 lb./in.^{3}
Specific Heat	0·23 cal./gm./°C.
Thermal Conductivity	0·27 cal./cm. sec.°C.
Melting Point	630°C.
Coefficient Thermal Expansion	27·1 × 10^{-6}/°C. (20-200°C.)
Electrical Resistivity	6·6 × 10^{-6} ohms-cm.^{3}
Electrical Conductivity ...	15·2 × 10^4 mho-cm.^{3}
Young's Modulus (E)	6·5 × 10^6 p.s.i.
Poisson's Ratio	0·3
Hardness	65-75 VPN
Impact Strength	Unnotched 6·0 to 8·0 ft. lbl. Notched (≡Izod) 1·0 to 2·0 ft. lb.

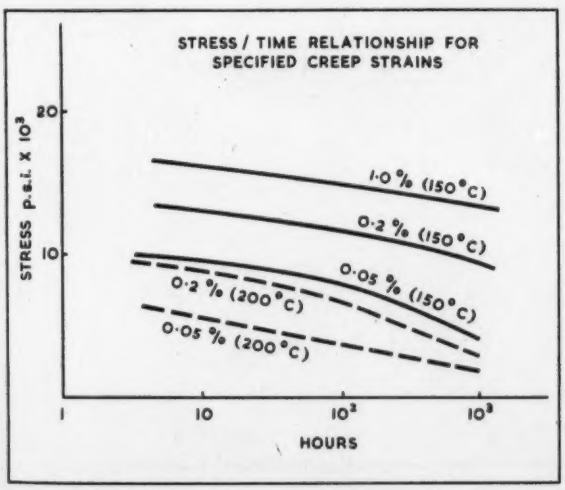
Design Data for Sand Castings:

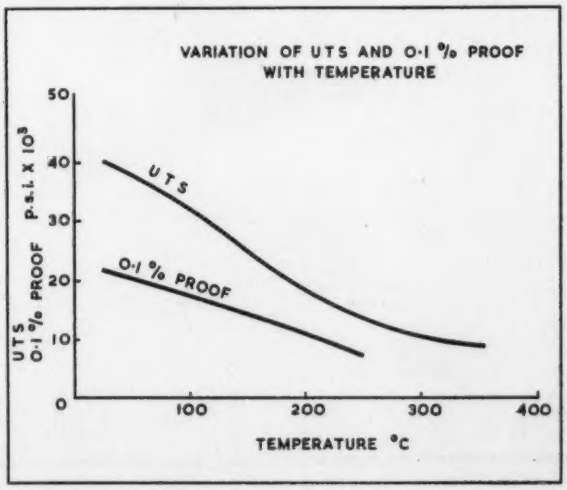
Min. wall thickness $\frac{1}{16}$ in. (may be reduced to $\frac{1}{8}$ in. for localised areas). Min. fillet radius 0·075 in. (should be as large as possible where castings are used at elevated temperatures). Suitable for pressure-tight castings and intricate shapes. Weldable by argon-arc process. Should be protected when in contact with dissimilar metals.

Data by courtesy of Magnesium Elektron Ltd





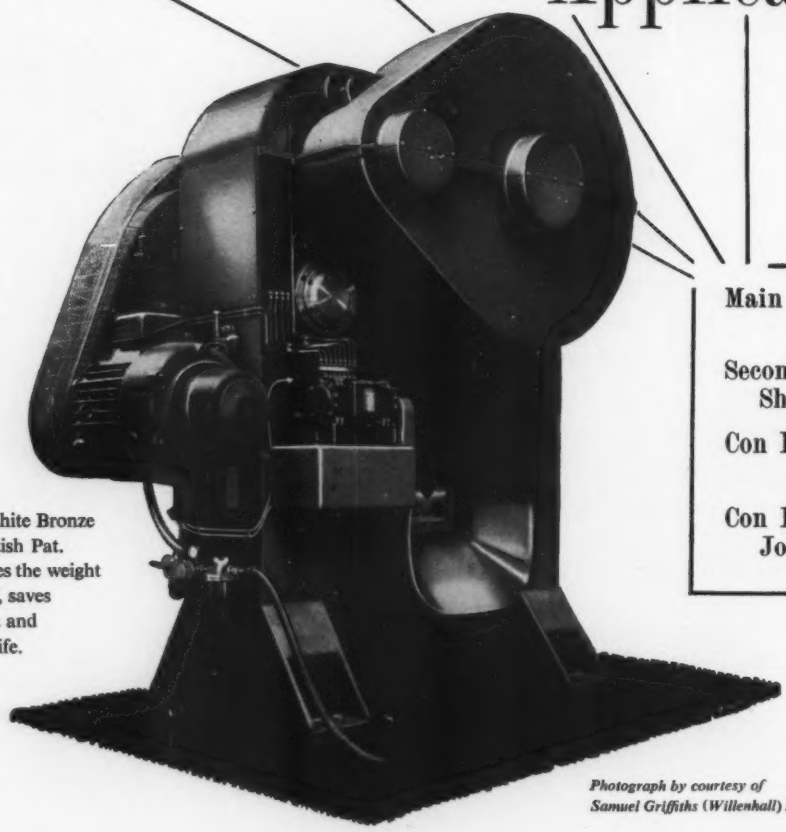




Here are further Excellent Examples of ALZEN 305 Bearing Applications

ALZEN 305

Regd. Trade Mark B 752748



Alzen 305 is the White Bronze Bearing Alloy (British Pat. 725818) that reduces the weight of bearings by half, saves 40 per cent. of cost and lengthens bearing life.

- Main Crank Shaft Bearings
- Secondary Motion Shaft Bearings
- Con Rod Big End Bearings
- Con Rod Knuckle Joint Bearings

Photograph by courtesy of Samuel Griffiths (Willenhall) Ltd., Willenhall, Staffs.

May we send you technical data and samples for testing

HILL ALZEN (SALES) LTD., P.O. BOX 22, Stringes Lane, Willenhall, Staffs.

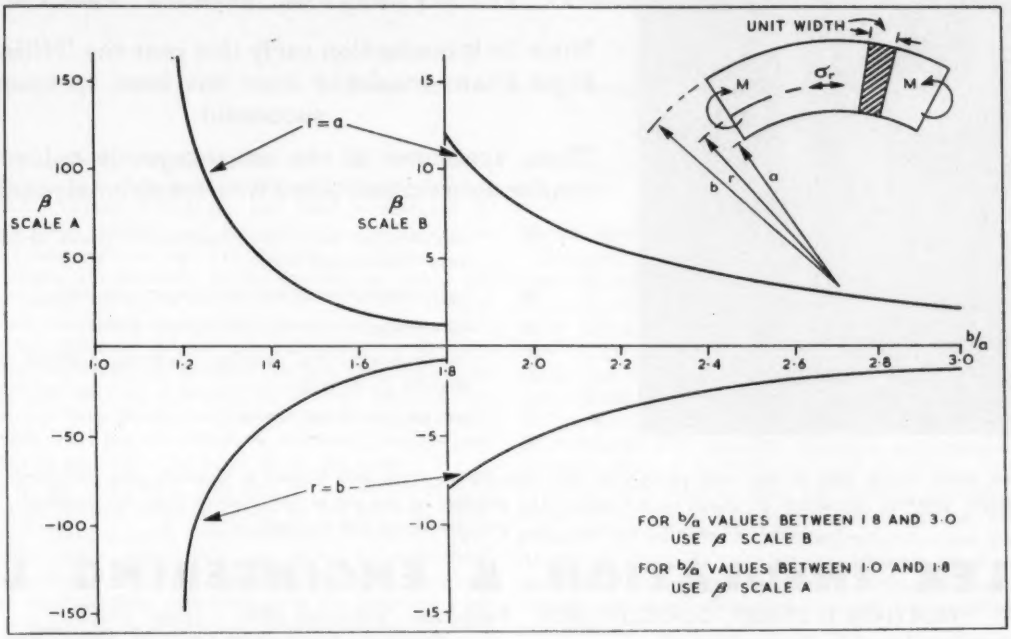
Telephone: WILLENHALL 227 (5 lines) Telegrams: Hill, Alzen 227 Willenhall

WhiteAd 4108

STRESSES IN CURVED BEAMS

Engineering Materials and Design
DATA SHEET No. 8

The upper curve may be used to evaluate the extreme fibre stress in a curved beam under elastic deflection. The curve at the foot of the page gives an approximate conversion for extreme fibre stresses in curved beams, assuming no deflection under load, and calculated by methods normally used for straight beams.



For unit width of beam, the stress at any radius, $r = \sigma_r =$

$$\frac{-4M\left(-\frac{a^2b^2}{r^2}\log\frac{b}{a}+b^2\log\frac{r}{b}+a^2\log\frac{a}{r}+b^2-a^2\right)}{(b^2-a^2)^2-4a^2b^2\left(\log\frac{b}{a}\right)^2} \qquad (1)$$

Stress at extreme fibres $\sigma_r = \dfrac{\beta M}{a^2}$ (2)

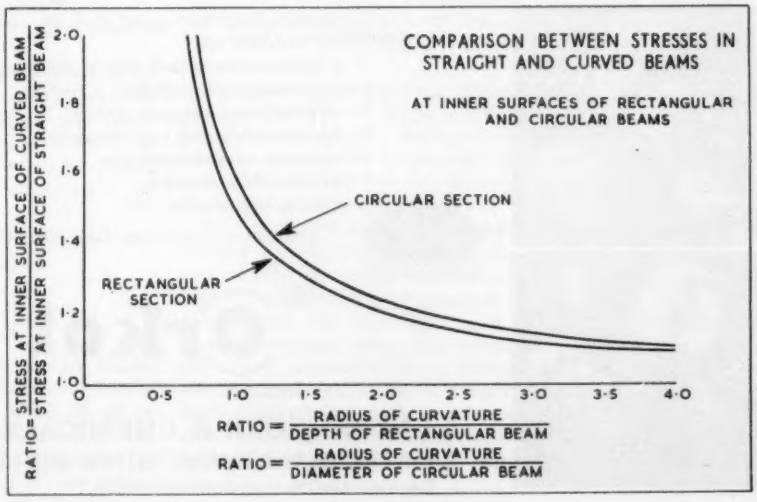
For beams of width t, Formula (1) becomes:

$$\frac{-4M\left(-\frac{a^2b^2}{r^2}\log\frac{b}{a}+b^2\log\frac{r}{b}+a^2\log\frac{a}{r}+b^2-a^2\right)}{t\left[(b^2-a^2)^2-4a^2b^2\left(\log\frac{b}{a}\right)^2\right]}$$

and Formula (2) becomes $\dfrac{\beta M}{a^2 r}$

where t is in the same length units as a, b, r and M.

For rapid approximation of stresses at extreme fibres using a correction factor for straight beams, the curve on the right should be used.



Data by courtesy of H. Vincent, B.Sc., A.F.R.Ae.S., senior stress engineer, Airspeed div., de Havilland Aircraft Co. Ltd.

The 'Millex 157' Rigid Foam insulated door is here to stay

Since its introduction early this year the 'Millex 157' Rigid Foam Insulated door has been spectacularly successful

These are some of the advantages it enjoys over similar doors constructed with traditional materials:

- one third less heavy, which ensures safer manual operation and lower maintenance costs.
- rigid construction gives higher impact resistance.
- heat leakage is *less than one-half that of cork.*
- incorporates fire retardant which has approval of Lloyds Register of Shipping.
- will not rot or decompose.

All doors can be built to your own specification and they can be attractively finished in plywood, glass reinforced plastic sheeting, aluminium or plastic coated steel. Any problem on the use of polyurethane foam for insulation, sandwich panels, containers etc., will receive the full attention of

MILLER INSULATION & ENGINEERING LTD

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London: 6/8 Upper Thames Street, E.C.4 Telephone: Central 6462

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OB.2

ULTRA HIGH STRENGTH ALLOY FOR MISSILES

FROM OUR OWN CORRESPONDENT

A NEW ultra-high strength alloy sheet steel for missile and rockets is now available from the U.S. Steel Corp. Designated Airsteel X-200, the new steel is designed to eliminate many welding and fabricating problems and at the same time provide high strength and toughness.

The unique characteristic of the material is that it develops a tensile strength of about 280,000 p.s.i. after cooling in air and tempering. In contrast, most other alloy steels require an elaborate oil or salt quenching to develop equivalent mechanical properties. The new steel attains its high-strength level by a careful balance of alloying elements which have proven suitable for rendering steel air-hardenable. This feature permits a fabricated missile part to harden by cooling in the open air of the shop.

Some of the fabrication tests that have been made with the material include forming, fitting up for welding, welding, heat treating and hydrospinning. Various types of missile motor cases with and without longitudinal welds have been made. In a typical missile application, the material, after forming and welding in the annealed condition, is heated to an established temperature and allowed to air-cool to room temperature. This operation air-hardens the steel. A tempering treatment at a lower temperature, followed by air cooling, imparts ductility and toughness and eliminates brittleness.

New High-Temperature Polyester Resin

Commercial production of the most heat-resistant polyester resin developed to date for reinforced plastics has been announced by Naugatuck Chemical Co., Div. of U.S. Rubber Co. The major feature of the new TAC-polyester (triallyl cyanurate-base) is the combination of high mechanical strength and good high frequency dielectric characteristics retained after exposure to sustained temperatures of 260 deg. C. and short time exposures to 540 deg. C. Water absorption after twenty-four hours is a low 0·03 per cent. Trade-marked Vibrin 136A, the resin is said to have transparency to radar waves approximately ten times that of conventional polyesters. Primary applications appear to be in radomes for jet aircraft.

Developed jointly by Naugatuck and Boeing Airplane Co., the material in laminate form (12 ply; 181 glass-cloth with Garan finish; 38 per cent resin content) has room temperature flexural strengths of 65,000 to 70,000 p.s.i. After a thirty-day water immersion, flex values of 60,000 to 65,000 p.s.i. are retained. Effects of temperature on flexural strength are as follows:

192 hr. at 260 deg. C. ...	35,000 to 45,000 p.s.i.
500 hr. at 260 deg. C. ...	43,000 p.s.i.
2,000 hr. at 260 deg. C.	12,000 p.s.i.
½ hr. at 320 deg. C. ...	22,000 p.s.i.
½ hr. at 370 deg. C. ...	11,000 p.s.i.

Laminates (60 ply; 181 glass-cloth with Garan finish; 38 per cent resin content; 0·6 in. thick) have a dielectric constant, dry at one megacycle, of 4·09, which drops to 4·07 at 9,375 m/c. under wet conditions. Loss tangent, dry or wet, at 9,375 m/c. is 0·0039. An unfilled casting (0·6 in. thick) of the resin has a dielectric constant at one megacycle, dry, of 3·6, which drops to 2·83 at 9,375 m/c. either wet or dry.

Metal Sputtering for Printed Circuits

Research on cathode metal sputtering at Bell Laboratories indicates that this century-old technique may be useful in producing precision printed circuits. It appears that entire circuits, including resisters, capacitors and leads, may be produced by the sputtering technique in which ionised gas molecules bombard a cathode, dislodging metal atoms which then redeposit on nearby surfaces.

Thin films of a number of high-melting-point metals can be produced. For example, tantalum and titanium with melting points of 3,000 deg. C. and 1,670 deg. C. respectively are laid down in films which show sufficiently high resistivity for use as a resister in printed circuits. The films generally are between a few hundred and a few thousand Ångströms thick. By masking the substrate, lines and patterns of any shape can be formed. Alloys such as nickel-copper and nickel-chromium can also be sputtered without difficulty.

"Printed capacitors" have also been made by combined sputtering and chemical methods. A tantalum film of the proper size and shape is first sputtered on the substrate and then anodically oxidised to form a tantalum oxide dielectric film. The counter electrode, a film of gold, can then be evaporated on the dielectric to form the capacitor "sandwich".

Copper leads can also be sputtered without difficulty to connect the various components. This technique is attractive, as it eliminates the need for organic adhesives.

Ceramic Honeycomb Structures Developed

Honeycomb sandwich structures of ceramics have been developed by two different companies, Minnesota Mining & Manufacturing Co. and Corning Glass Works. These thin-walled ceramic materials have the high strength-weight characteristics inherent in all honeycomb sandwich materials, but provide much higher heat resistance and a high degree of chemical inertness, dependent on the ceramic used.

The ceramic honeycomb produced by American Lava Corp., subsidiary of 3M, is a thin-wall material which can be fabricated, prior to firing, by methods similar to those used in sheet-metal fabrication. The final product is no longer ductile and has the thermal and chemical stability inherent in the ceramic used.

For producing constructions by the Cercor process developed by Corning Glass Works, a variety of materials can be used, including Corning's new polycrystalline glass ceramic, trade-marked Pyroceram.

Materials for forming such honeycomb structures include ceramics which can withstand temperatures up to 980 deg. C. with virtually no thermal expansion and which can operate continuously at temperatures up to 700 deg. C. Such materials are resistant to both oxidation and corrosion. Materials are available with coefficients of thermal expansion as low as 1×10^{-7} per deg. C. (from 0 to 300 deg. C.).

New Books

The Analysis of Grid Frameworks and Related Structures, *by A. W. Hendry and L. G. Jaeger.*

THIS publication is the first of its kind on this subject in English and it has been expressly written for designers and advanced students.

The book opens with a brief review of existing methods of analysis for open-grid frameworks, interconnected bridge girders, slabs and cellular plated structures and states that an integrated treatment is required which is suitable for the analysis of all such structures.

Such a treatment, under the name of grid-frame theory, is presented in this book, and it is shown to be an easily applied and accurate method of calculating the distribution of concentrated loads amongst the main girders of a multi-grid structure. The method makes extensive use of harmonic analysis and great advantages are claimed for its use in simplifying all interconnected beam deflection problems. Only one major assumption is made, namely that the transverse members of a grid may be replaced by a uniformly spread medium over all or part of the span. Hence, the flexibilities of various longitudinal members expressed in harmonic form are related to the flexibilities of the transverse continuum, and by use of higher order terms in the harmonic series greater accuracy can be achieved.

The book has been divided into three main parts—I—Design Calculations; II—Analysis; and III—Experimental Studies—although the reviewer feels that this order is not necessarily the best. In part II theoretical analyses are developed, following an introductory chapter on harmonic analysis, and then applied in part I. The results obtained for a wide variety of practical problems, related to the design of bridge and other structures, are presented, and once the terminology has been mastered such design calculations could be performed directly without following through the theoretical solution. The experimental studies provide confirmation of the method as applied to idealised model structures and to actual structures.

To summarise, this book should prove a welcome addition to the theory of structural analysis; its layout is good, and for anyone with a reasonable knowledge of elementary calculus it is easily understood. (*Chatto & Windus,* 50*s.*)

D.J.J.

The Metallurgy of Vanadium, *by William Rostaker.*

A voyage of discovery for the reader is a phrase which could be aptly applied to this book, the author having successfully written and arranged highly technical data in such a way as to appeal to both student and metallurgist.

The contents of the book are logically arranged dealing with the extraction of vanadium, its physical and mechanical properties and includes a number of constitutional diagrams. The mechanical properties of the various vanadium alloys are dealt with in some detail, as are such techniques as forging, extruding, rolling, etc. A most useful section of the book deals with the oxidation and corrosion properties of vanadium, and this is of no little importance, since the embrittlement of the metal is closely associated with these parameters.

The chapter dealing with the metallography is comprehensive, covering methods of mounting specimens, grinding, polishing and etching. The microphotographs of the crystal structures are well above the average, as indeed are all the illustrations.

This publication contains an excellent bibliography and could be thoroughly recommended to all those interested in metals. (*John Wiley & Sons Inc.,* 68*s.*)

R.D.C.

Technical Publications, *by C. Baker, A.F.Ae.S.*

Mr. Baker has spent many years as head of the technical publications department of a major aircraft company and is not only well-qualified to write on the subject from that angle but, as an engineer, is also able to view the results objectively.

This book contains much sound guidance which should be followed by a prospective author, whether he is writing a text-book, publicity copy or articles for a technical journal.

The contents cover the various forms of technical writing, the correct use of words and the value of illustrations. Associated with these are descriptions of printing techniques and proof correcting. (*Chapman & Hall Ltd.,* 36*s.*)

R.D.C.

Determination of Compressibility of Metal Powders (B.S. 3029 : 1958)

The three clauses of this new publication specify the die and set to be used (together with an illustration), the method of determining the weight of powder required, complete detail of the "procedure" and the manner of expressing the result obtained. (*British Standards Institution,* 3*s.*)

LETTER TO THE EDITOR

"The 'New' Extrusion Process"

Sir,

In your November 1958 issue ("Materials in the News"), mention is made of a "new extrusion technique" where two opposed punches cause a slug to simultaneously forward and backward extrude, producing a tubular component with a central diaphragm. As you reported, this technique was discussed at the Jubilee autumn meeting of the Institute of Metals, where certain contributors wrongly implied that this was a new method of extrusion. A glance at the appended references will show that it has been used for some time in the cold extrusion of steel.

In the late nineteenth century Alexander Dick, on whose inventions the modern process of extrusion has been founded, patented the idea of extruding steel simultaneously through dies placed at both ends of the container.[8]

Whilst there is little advantage in using the technique for non-ferrous metals, there are factors which make it more suitable for cold steel extrusion.

In the backward extrusion of steel cans at room temperature, the limiting factors are the compressive stress in the punch which, irrespective of degree of reduction, is never less than approximately 120 tons/in.^{2} and its tendency to buckle. The pressure required for simultaneous backward and forward extrusion is somewhat lower than that required for the backward method only. The resulting stresses in the tools are therefore lower and a smaller capacity of press is required. A longer hollow product of the same cross-sectional area can thus be produced by this method, since two individually shorter punches are used which are less heavily loaded and hence more stable.

Stripping the product from the tool may be difficult and the central diaphragm may require subsequent removal. The main disadvantages of this method lie in the possibility of material being less worked during extrusion and a tendency to produce a form of 'extrusion defect' at the centre portion of the tube. This may possibly account for its limited application in the non-ferrous field.

James McKenzie

Plasticity Div.,
Mechanical Eng. Research Lab.,
East Kilbride.

1. Crane, E. V., "Cold Extrusion of Steel and the Use of Hydraulic Presses", *Sheet Metal Industries,* 1953, **30,** (314), 464.
2. Verson, J., "Practical Tooling for Cold Extrusion", *Metalworking Production,* January 17, 1958.
3. Feldmann, H. D., "Fliesspressen", Z.V.D.I., 1951, **93,** 434.
4. Heine, H., "Present Position of Cold Heading, Cold Pressing and Flow Pressing in the Manufacture of Bolts", *Werkstattstechnik und Maschinenbau,* 1950, **6,** 40.
5. Hauttmann, H., "Cold Extrusion of Steel", *Iron Age,* 1951, **167,** 11, 99.
6. Hauttmann, H., and Pessl, H. J., "The Aluminium Bearing, Non-ageing Steels and their Cold Extrusion", *Steel Processing,* 1950, **34,** 11, 557.
7. Lloyd, T. E., and Kopecki, E. S., "Cold Extrusion of Steel", *Iron Age,* August 4, 1949.
8. Pearson, C. E., "The Extrusion of Metals", Chapman & Hall.

WHAT'S NEW IN MATERIALS & COMPONENTS

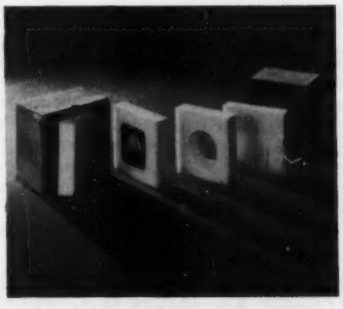
Polycarbonate Insulation

An electrical insulation foil based on a new type of polyester (polycarbonate) and called Makrofol is now available in this country. Because of its chemical, electrical, mechanical and other physical properties, this foil is said to be excellently suited for the various types of insulation employed in the electrical industry. It can be used for all purposes where insulation foils have previously been used. In addition, its particular properties are said to give it a number of new applications; for example, for slot-lining insulation in electric motors, for layer insulation in transformers and coils and in the manufacture of electrical capacitors. J. M. Steel & Co. Ltd.

EMD 348 for further information

Flexible Foam

Flexible foam is an open-cell structure manufactured in the U.K. and adapting itself to numerous industrial applications. There are three types commercially available—polyether, polyurethane and vinyl—and they are normally supplied in individual shapes and sizes as required.



The material has a high shock absorbency and densities range from 1¼ lb. to 2¼ lb./ft.³ When used for sealing or protecting delicate instruments the performance is said to compare favourably with felt and cellulose acetate wadding, but with improved stability. The three types are now available from Aeropreen Products Ltd.

EMD 349 for further information

Epoxy Protective Coating

This material, based on epoxy resins modified with suitable amines, is a two-can product supplied as a base and adduct. It is known as Epinamel A.C. and is claimed to have exceptional properties which have not before been available in conventional organic coatings. Amongst them are a high resistance to many chemicals in liquid or solid form at low and high temperatures. The coating can be cured at room temperature or stoved at temperatures between 120 deg. C. and 205 deg. C. Application is by spray or brush. Epinamel A.C. is primarily for use as a lining material for tanks carrying corrosive chemicals which might attack the unprotected metal or for containers of foodstuffs to prevent contamination. Arthur Holden & Sons Ltd.

EMD 350 for further information

Polyurethane Coatings

Luxol polyurethane coatings embody the latest discoveries in paint technology which enable—for what is thought to be the first time—cold-hardening surface coatings to be offered having the nearest approach to the hardness and appearance of vitreous enamelling.

These coatings, which are not dependent on air oxidation for film formation, are composed of selected polyesters hardened with a non-toxic isocyanate. They dry with a hard porcelain-like finish and are claimed to have excellent water resistance. Curing is satisfactory at low ambient temperatures. British Paints Ltd.

EMD 351 for further information

Heavy-duty Coating

A new and improved type of heavy-duty plastics coating has just been introduced under the name of Epiglo-C. This is an epoxy-based material, but of a different kind from those widely used in all branches of industry today. With Epiglo-C, it is said that extended tests over a very wide range of industrial applications have proved that the material can be successfully used under adverse weather and other conditions. It is therefore an all-the-year-round material as far as application is concerned, and will give a high degree of protection to steelwork, concrete, brickwork, wood and other surfaces. Corrosion Ltd.

EMD 352 for further information

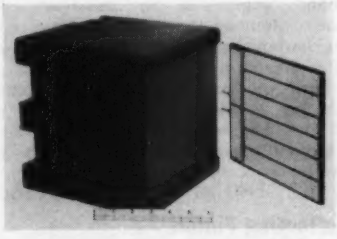
Zinc/Silicate Paint

A recent development in the technology of corrosion is Dox-anode paint, which is composed of entirely inorganic materials. It is therefore non-inflammable and produces no fumes or gases when sprayed. An unusual factor of this paint is that when applied to steel old rust should not be removed, apart from loose flakes. Dox-anode is supplied in two parts, a liquid and a powder, and these are mixed just prior to application and must be used within 24 hr. Among the outstanding properties claimed are corrosion resistance against sea water and all hydrocarbons, and it is said to withstand a temperature of 500 deg. C. indefinitely. Industrial Services.

EMD 353 for further information

Sprayed Heater Surface

A unique process for manufacturing an electrically-heated surface is known as Spraymat, which consists of three layers—a metallic element embedded between two layers of insulation—which are built up by spraying one after the other directly on to the surface to be



heated. In this way a very light and robust heater can be easily applied to components with a complicated contour. Surface temperatures of over 100 deg. C. can be maintained and heaters can be designed with power loadings in excess of 40 watts in.² The heater is said to be completely waterproof and resistant to most mild acids and alkalis. D. Napier & Son Ltd.

EMD 354 for further information

Acid- and Alkali-resistant Cement

A recent development is a cement that is claimed to withstand permanently the chemical actions of acids and alkalis. It is composed of polyester resins, combined with high-quality inert fillers, scientifically blended to produce an impermeable cement. It is available in the form of a powder and solution, each supplied separately. The mixing of the solution and powder is said to be simple, the resulting cement having a putty-like consistency and is easily applied.

Known as Alcuma, it sets to a very close, stone-hard texture which is completely innocuous. It is uniformly acid-, alkali- and water-resisting throughout its entire mass. It is said to be very satisfactory for bedding and jointing, or pointing, vitrified tiles and bricks in the construction of acid- and alkali-resisting floors, benches, tanks, etc., and can be used for sealing acid-carrying pipes. J. H. Sankey & Son Ltd.

EMD 355 for further information

Plastic-faced Laminates

A range of new hard and tough plastic-faced laminates has been announced for application to a very wide field of applications. This new material, known as Duralite, is supplied as a facing for hardboard, plywood, blockboard, particle board, aluminium and galvanised steel. It is claimed to be resistant to abrasion and heat, as well as to water and a wide range of chemicals. Duralite is available in two types of grain finish and in seven colours. Borst Bros.

EMD 356 for further information

Insulation Material

Millex 157 is the name given to a new insulation material consisting of a rigid-foamed resin of low thermal conductivity and remarkable strength, prepared from an isocyanate resin. Although basically more expensive than cork, it is claimed that it can be applied more cheaply overall. Millex 157 is an inorganic compound impervious to moisture and fumes, immune to growth of fungi and the harbouring of insects and therefore of a greater hygienic standard.

Heat conductivity is only 0·05 B.t.u. per deg. F. compared with 0·105 B.t.u. of cork. The material incorporates a fire-retardant to reduce fire hazard. Miller Insulation & Engineering Ltd.

EMD 357 for further information

Reflecting Finish

Alux surface finish for aluminium has recently been introduced to provide a glass-hard finish which is claimed to give a higher degree of reflectivity than any conventional material and to retain it even in wet and chemically corrosive atmospheres. Alux is also said to repel dust and dirt and to be better than silver and chromium plate in this respect. This finish is highly resistant to heat, and can be supplied in many colours which are not prone to fading. Veritys Ltd.

EMD 358 for further information

Alkaline Lubricating Oil

As a result of considerable research to combat the excessive wear in diesel engines through the use of cheap heavy boiler fuel, Mobilgard 593 lubricating oil has been developed. This oil is made alkaline to neutralise the acid products of combustion of high-sulphur-containing fuels. It is compatible with conventional lubricants and does not affect lubrication performance when so mixed. It does not form stable emulsions with water and is claimed to be stable in storage under all conditions. Mobil Oil Co. Ltd.

EMD 359 for further information

P.T.F.E Bearings

A range of sintered porous metal bearings, impregnated with p.t.f.e., which can be applied in much the same way as oil-retaining bearings, is available with the name of Polyslip. Intended for applications where petroleum lubricants are undesirable, they offer the engineer an alternative which can be run dry, although the presence of a fluid improves performance. The range offered includes (a) two special variations of the oil-retaining bearing adjusted to accommodate p.t.f.e., (b) a type in which a thin layer of porous metal in the bore, impregnated with p.t.f.e., is bonded to a bronze backing member produced from cast stock or by powder metallurgy, and (c) in the form of a moulded powder part in which the interstices have the shape produced by the packing of uniform spheres of p.t.f.e. Bound Brook Bearings Ltd.

EMD 360 for further information

Polyethylene-coated Aluminium

A material which is said to combine the chemical resistance of polyethylene with the impermeability of aluminium foil has recently been developed as a result of research into a method for coating aluminium foil with a very thin layer of polyethylene. The material can be heat sealed and has great strength. A typical example of this product is an aluminium foil 0·0012 in. thick coated with a 0·00075 in. thickness of polyethylene which protects the metal from attack by a very wide range of acids and alkalis up to temperatures of around 60 deg. C. Fisher's Foils Ltd.

EMD 361 for further information

Thermocouple Platinum

It has now been found possible to produce a thermo-element-quality platinum wire having a fibrous structure which resists recrystallisation at elevated temperatures and which shows remarkable resistance to grain growth. Its thermo-electric behaviour is said to be indistinguishable from that of conventional thermo-element platinum, but it is claimed to be mechanically superior and therefore to have a longer life when subjected to prolonged heating at high temperatures. Engelhard Industries Ltd.

EMD 362 for further information

New Chipboard

Wood chipboard, known as Euborite, is now available in this country. It is made from specially graded hardwood chips and bonded by phenolic resin. The outer plies are of gaboon/mahogany veneer and it is available in all thicknesses from ¼ in. up to 1 in. Y. Goldberg & Sons Ltd.

EMD 363 for further information

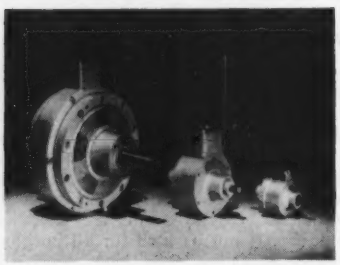
Aluminium Alloy Extrusions

An undesirable feature of high-strength extrusions to B.S. L65 is a zone of coarse grain at the periphery; its presence adversely affects such properties as tensile strength, fatigue strength, machinability and stress corrosion. Consequently, it is general practice when designing sections or ordering bar to make an appropriate allowance for this zone, so that it can be removed by machining and full advantage taken of the superior properties of the underlying metal.

A special technique has been developed whereby these high-strength extrusions can be made available free from peripheral coarse grain, yet retaining the desirable features associated with conventional production methods. So far attention has been mainly directed to the manufacture of the simplest shapes such as round bar, but future development of this new technique will be directed along those lines which will be of maximum benefit to users. They are known as Kynal P.F.G. extrusions. Metals Division, I.C.I. Ltd.

EMD 364 for further information

Magnetic Particle Coupling



This new coupling transmits torque by means of a ferro-magnetic powder which fills the gap between the inner and outer rotor. The degree of coupling depends on the magnetic flux density in the gap which is controlled by a stationary exciting coil. On full excitation the coupling becomes solid, so that there is no slip causing generation of heat and loss of efficiency. Among the claims made for this unit are absence of jerk and judder during take-off, accurate control of torque by the excitation current and smooth operation. Sizes available have torque capacities in the range ½ to 200 lb./ft. S. Smith & Sons (England) Ltd.

EMD 365 for further information

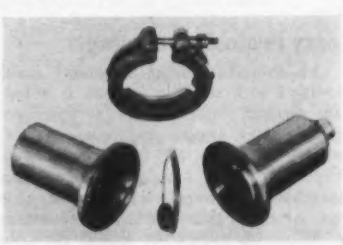
Hose Coupling

A new free-end hose coupling for pneumatic systems, gases or liquids has been introduced for working pressures up to 250 p.s.i. The couplings are robust and yet light in weight when constructed of nylon. One of the advantages of the new system is that no hose fittings are required and, therefore, it is claimed that assembly time can be cut. Airtech Ltd.

EMD 366 for further information

All-metal Tubing Joint

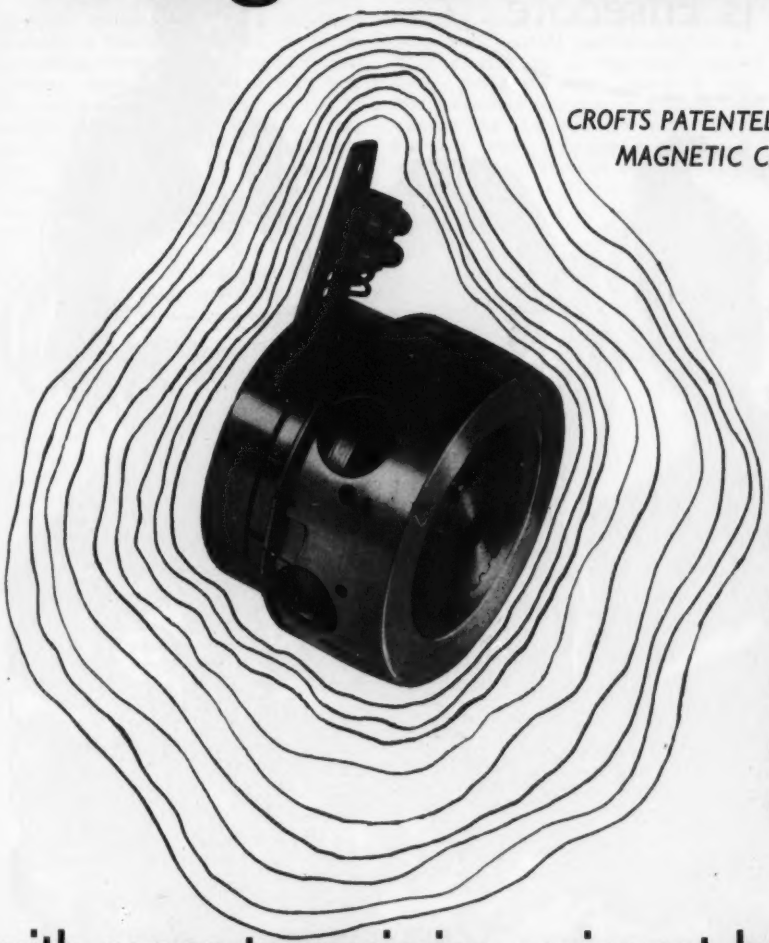
Conoseal is a new development which provides metal gasket compression with flexibility and sealing qualities formerly obtained only through the use of organic seals. The seal is recommended for high-pressure pneumatic systems, hydraulic systems, fuel and exhaust systems and is claimed to be suitable for use with liquid oxygen, exotic fuels, oxidisers, exhaust gases and liquid metals. It is available in



three performance ranges covering −180 deg. C. to 1,000 deg. C. and up to 6,000 p.s.i.g. King Aircraft Corp.

EMD 367 for further information

design for automation



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- *Slip rings and brushes entirely eliminated.*
- *Instantaneous response and rapid, shock-free, pick-up to full load transmission.*
- *Minimum field decay time and residual drag due to isolation of magnetic assembly.*
- *Trouble-free operation with single point adjustment.*
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- *Compact and easily interchangeable with many existing units.*
- *Drives in either direction of rotation.*
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makers of: *Clutches, Conveyor Drives, Couplings of all types, Double helical gear units, Fabricated steelwork, Geared motors, Hydraulic couplings, Iron, steel and non-ferrous castings, Machine-cut gears of all types, Motorised rollers, Patent Taper-flush-bushes, Plummer blocks, Shaft-mounted gear units, Special machinery drives, Spiral bevel gear units, Turbine gears, V-Rope Drives, Variable speed drives, Worm reduction gears.*

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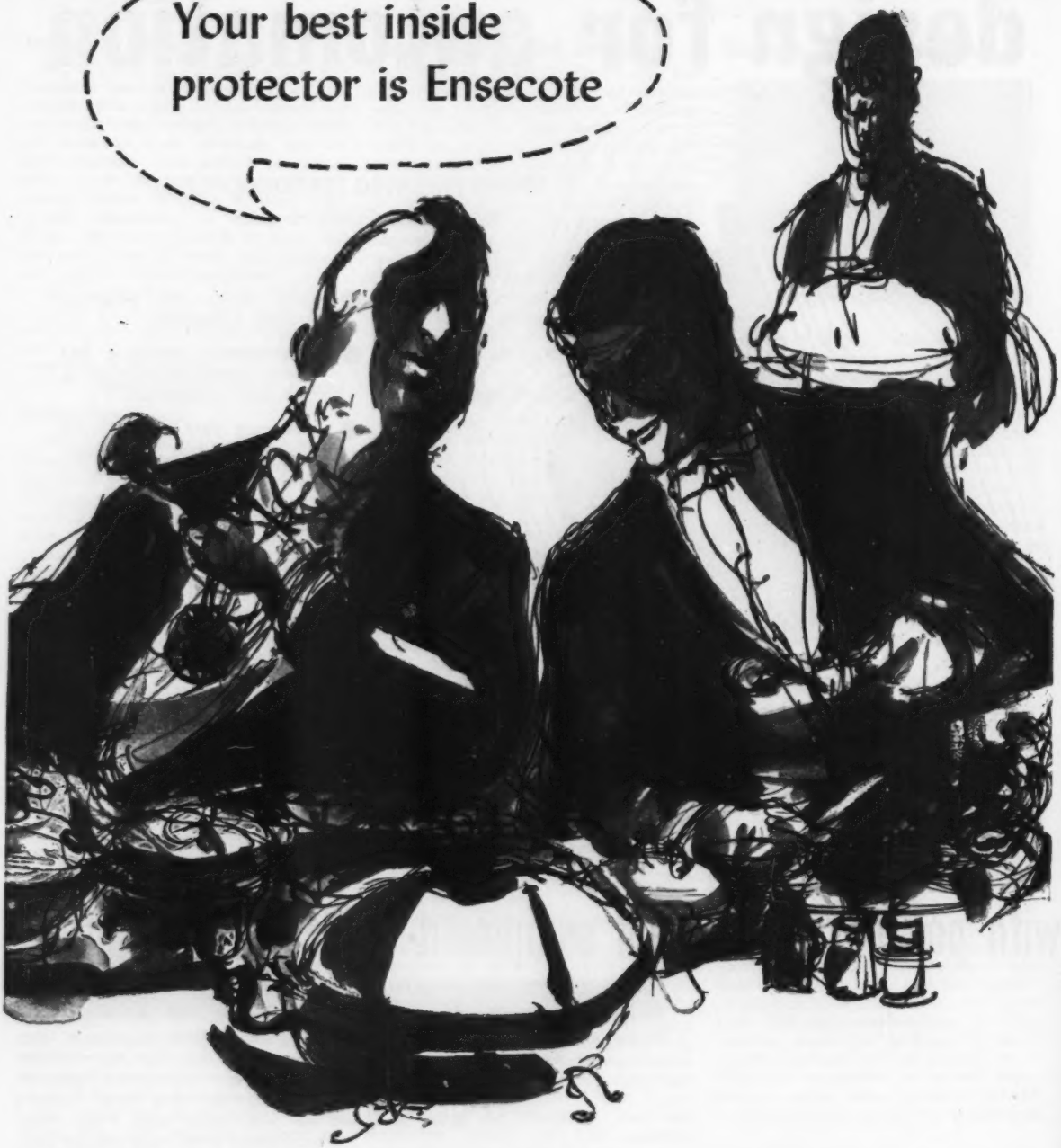
EMD 316 for further information

Your best inside protector is Ensecote



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Polyethylene Letters

A range of polyethylene letters specially produced for use in moulding patterns is now available and the letters are claimed to have all the useful characteristics normally associated with lead characters. They are pliable and can be moulded to any normal countour; they can be glued or pinned without difficulty and are claimed to be unaffected by water. They are extremely resilient and therefore hand or machine ramming will not produce burrs and cause other damage. The inherent self-lubricating property is said to overcome any tendency to stick. Aldridge Plastics Ltd.

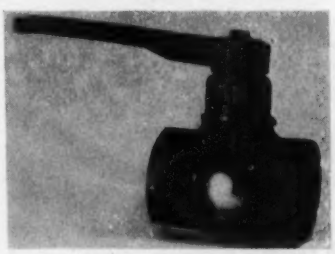
EMD 368 for further information

Full-flow Valve

The H.P. full-flow valve is for use in pipelines to control the flow of liquids and gases.

It is intended for the oil, marine, gas, chemical and fruit drink industries, for breweries, distilleries, dairies and laundries, and for food—such as ice-cream—which may be passed through pipes. In the small sizes it may be applied to general instrumentation.

The valve has flanged or socket ends for incorporation in the pipeline and varies in diameter from $\frac{3}{32}$ in. to 4 in. Pressures may vary between 140 p.s.i. and 5,000 p.s.i.



A three-way or four-way valve is also made, working on the same principle. The ball is pierced with two holes, forming an L- or T-shaped bore through it. Hydraulic & Pneumatics Ltd.

EMD 369 for further information

Lightweight Air Hose

This rubber hose is covered with rayon braid and has a bore of $\frac{5}{32}$ in. It is lighter, more flexible and gives greater ease of handling than the standard-type hose, and is also less expensive. A comparison between a 10-ft. length of $\frac{5}{32}$-in. hose and connectors and a 10-ft. length of $\frac{3}{16}$-in. hose and connectors shows that the length of smaller hose weighs 5¼ oz. as opposed to 25 oz.

From the operator's point of view, this is a most useful development, since the use of the new air hose reduces fatigue and gives exceptional freedom of movement. It is intended for use particularly with the L.900 spray gun. Alfred Bullows & Sons Ltd.

EMD 370 for further information

Spray Nozzle

The body of this nozzle is manufactured from high-quality bronze and all working parts from suitable hard-wearing alloys. It is covered by a renewable rubber cover, giving the spray nozzle a long life, preventing scratches or damage and withstanding exposure to heat. It is operated with a trigger-type shut-off valve and a variation of water discharge

from a mist spray to a pencil jet is controlled by hand pressure on the trigger. The shut-off valve closes automatically when the trigger is released by the operator.

The spray nozzle is fitted with nylon bushes which have proved to be more durable than metal bushes. It is usually supplied with two adaptors for use with either ½-in. or ¾-in. hose, but any size adaptor is available. A fire-brigade fitting is also available. The spray nozzle effects a considerable saving in water; for example, an uncontrolled hose at 25 p.s.i. gives an output of 40 gals./min. compared with 2½ gals./min. using the nozzle jet. Meynell & Sons Ltd.

EMD 371 for further information

Shaft Seal

A new seal has been designed and developed to provide an efficient gland for housings which carry rotating shafts running at high speeds coupled with high fluid temperatures and pressures. Sealing is effected axially and therefore the shaft which the sealing member does not contact need not be hardened. The Impax seal, as it is called, is claimed to be practically frictionless in operation, to be self-adjusting for wear and, since wear is very slight, its working life is said to be normally equal to that of the machine to which it is fitted. The seals are supplied with either special bronze or Resax sealing nose, dependent on the fluid to be sealed. Resax is a graphite-filled phenolic resin. Charles Weston & Co. Ltd.

EMD 372 for further information

Switch Tripping Equipment

A re-designed range of self-contained steel-clad tripping units has recently been introduced. Each of the new units includes a battery of the nickel cadmium alkaline type which, with its long life, reliability and instantaneous voltage recovery, is ideally suited for use in switch tripping equipment.

The battery is arranged in a single tier, which allows extra space above the battery, to facilitate inspection. A compartment is also provided beneath the battery for the storage of tools and accessories.

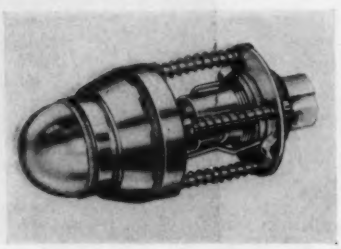
The cabinets are of folded steel construction with modern styling, and incorporate a sloping control panel with a pale blue fascia instead of the usual independent labels. Rectangular flush meters with 3-in. effective scales are fitted in the panel. Nife Batteries Ltd.

EMD 373 for further information

Indicator Lamp Unit

Indicator lamp units of two types, one for use on circuits up to 250 volts and the other for low-voltage circuits to 24 volts, have recently been introduced.

The full-voltage type incorporates a special patented feature which enables the bulb to be removed from the front of the panel despite a small-diameter unit and the recessing of the bulb well back to avoid overheating of the glass



lens. In order to provide for removal of the bulb, the lamp and its holder are so mounted that they can be pulled forward into a position which enables the bulb to be replaced without difficulty.

The units are fitted with two sealing gaskets to ensure that oil and moisture cannot enter when used on machine tools or similar applications. Accommodation is provided for panels up to ¼ in. thick, and lenses in red, amber, green, blue and clear glass are available and other colours can be provided if required. The lenses are designed to provide exceptional visibility both from the front and the side. The outside of the lens is smooth glass and can readily be kept clean and free from dirt. Craig & Derricott Ltd.

EMD 374 for further information

Chemical-resistant Hose

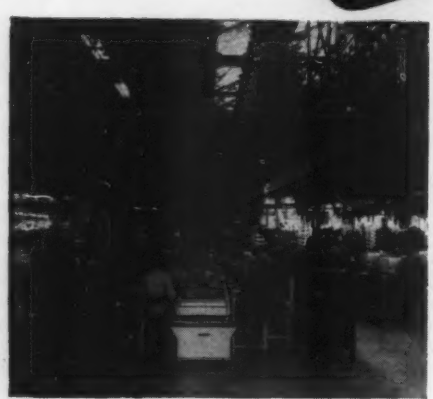
A new polyethylene-lined rubber hose for the conveyance of concentrated mineral acids has been developed under the trade name of Valithene.

The hose, which represents an impor-

EMD 317 for further information

"production of each job from raw materials to finished component is under constant supervision . . ."

Metallurgia



UNTIL we introduced and developed our new "die-line" technique, the accepted method of producing pressure die-castings was by batch production. It involved handling, transit and storage between operations and the risk of damage to critical surfaces—particularly those intended for subsequent plating—was always present. It was uneconomical in floor space and made supervision difficult. All this has changed. The new die-line permits continuous production with all the finishing operations performed on a single conveyor line. Every operation is under constant supervision and, as no casting can touch another, impact damage has been eliminated. If you have a project where quantities are substantial, these facilities are at your service and your enquiries would be welcomed.

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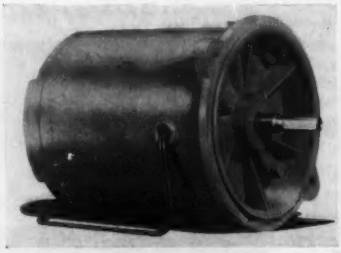
tant advance over stainless-steel or rigid polyethylene pipelines on account of its flexibility, is expected to have a number of uses, particularly in the chemical industry. Applications for which it is considered suitable include temporary pipelines, pipelines for dye stuffs, lead pipe replacement in chemical plant, chlorine water plant pipes, pharmaceutical and fine organic chemical plant, and the conveyance of liquid foodstuffs, wines and spirits and soap detergents.

Sizes in which the hose is available range from ½-3 in. bore, and lengths of up to 60 ft. can be supplied. Working temperatures should, in general, not exceed 60 deg. C., although very low-pressure steam may be used for cleansing, provided that the other end of the hose is open to the atmosphere. Maximum working pressure is 50 p.s.i. Dunlop Rubber Co. Ltd.

EMD 375 for further information

Oil-burner Flange Motor

A recent addition to the range of Merlin f.h.p. motors is the oil-burner flange type for use on heating equipment. The motor, which may be obtained in either ventilated or totally-enclosed fan-cooled types, complies dimensionally with NEMA standards. Horsepower



ratings are offered as follows for 1,500-r.p.m. motors: ventilated type, $\frac{1}{16}$ to $\frac{1}{3}$ single phase; ventilated type, $\frac{1}{4}$ to $\frac{1}{2}$ three phase; totally-enclosed type, 0·8 to $\frac{1}{3}$ single phase; totally-enclosed type, $\frac{1}{4}$ to $\frac{1}{2}$ three phase. Other speeds are available.

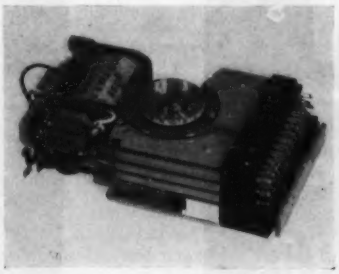
Sleeve bearings with felt-packed oil cavity are fitted as standard, but ball bearings may be fitted as an extra. The shaft has a milled flat for fixing fan or pulley and rotation is anti-clockwise. The motor is provided with 20-in. loose leads. Thermal cut-out protection, with automatic or manual reset, can be added at an extra charge on single-phase motors. Brook Motors Ltd.

EMD 376 for further information

Miniature Uniselector

A remarkably small plug-in uniselector switch with 36 outlets and measuring less than 4 × 2¼ × 1¼ in. has been introduced for use in automatic systems. Occupying the space of a G.P.O. 3,000-type relay, this uniselector (designated the 2250) is of particular interest to builders of electrical automatic machines. It weighs 12 oz. complete.

It is said to operate for two million revolutions without need for readjustment, and has a working life of at least eight million revolutions before replacement of any part. It is designed for



operation in 22-volt or 50-volt circuits in its standard versions and incorporates its own spark-quench device. Siemens Edison Swan Ltd.

EMD 377 for further information

Photoelectric Switch

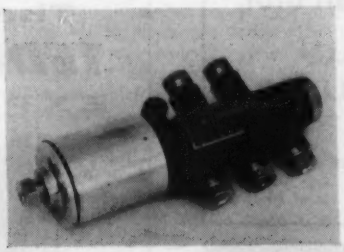
A new range of miniature photoelectric equipment uses a photocell having a very small sensitive area giving a high degree of operational accuracy, while its small dimensions enables photoelectric control to be used where space is severely limited. The photoswitches are actuated by a change in the density of light falling on the cell and this change is usually effected either by interruption of a direct light beam, or by interruption or change in the intensity of a reflected light beam. Relay units are available embodying a withdrawable chassis to facilitate installation and servicing and these, too, have reduced dimensions. Elcontrol Ltd.

EMD 378 for further information

Cylinder-operated Valves

A new range of cylinder-operated valves has been designed to ensure positive movement of the valve member under extremes of operating conditions. They are single-or double-cylinder operated, two-, three or four-way valves of $\frac{1}{8}$-in. and ¼-in. sizes.

The large piston area provided by the cylinder gives a greater thrust to the



valve sliding member, an important safeguard against out-of-sequence operation resulting from, for example, adverse weather conditions. Maxam Power Ltd.

EMD 379 for further information

Plastics Stopcock

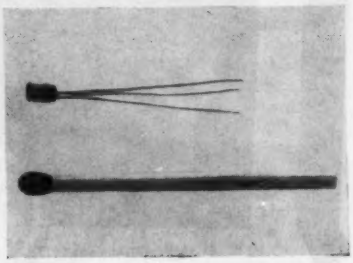
The new E-Mil stopcock is made from p.v.c. tubing with h.d. polyethylene housing, and is virtually unbreakable. The screwhead is of registered design, giving easy finger control and the precision thread ensures that the stopcock provides for micro-control or fast flow, from approx. 0·0002 to 1 ml./sec., with extreme accuracy. H. J. Elliott Ltd.

EMD 380 for further information

New Transistors

The type OC75, a new addition to the range of available germanium a.f. transistors, is intended for applications similar to those of the long-established OC70 and OC71 types, but in cases where a substantially-higher current gain is required. Maximum current gain of the OC75 is 130 (minimum 60). Apart from the increase in gain (and a necessary corresponding increase in collector leakage current for grounded emitter connection), the characteristics of the three types are identical.

Other new developments are a germanium transistor (see photo) designed for portable equipment such as hearing aids which is 50 per cent smaller than sub-miniature types previously used, a



high-temperature transistor consisting of a silicon alloy junction of the p.n.p. type and a phototransistor smaller than a 3d. piece. Mullard Ltd.

EMD 381 for further information

Gas-bearing Circulator

The rotating parts of the NFB circulator are carried on gas bearings which use the pumped fluid as lubricant. All moving parts are contained within a sealed pressure vessel, the electrical leads being brought out through vacuum-tight seals.

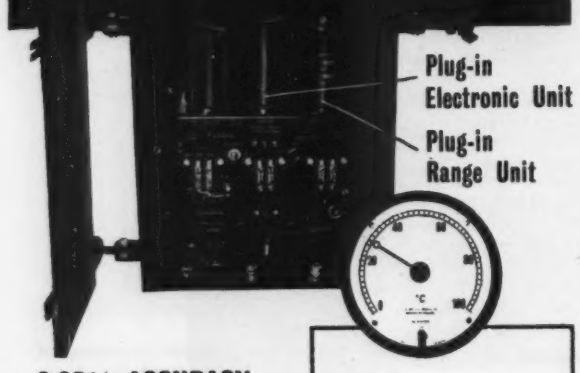
The circulator may be used in applications where it is required to pump gas at high pressures and temperatures with minimum, near-zero leakage. It is specifically designed for nuclear experiments where these requirements frequently occur, but can be used for engineering experiments to circulate air, carbon dioxide or helium at all conditions up to 450 p.s.i. abs. and 450 deg C. and will operate over a speed range of 10 : 1 when driven by a variable-frequency a.c. supply. Ruston & Hornsby Ltd.

EMD 382 for further information

EMD 318 for further information

NEW

Accurate TEMPERATURE MEASUREMENT



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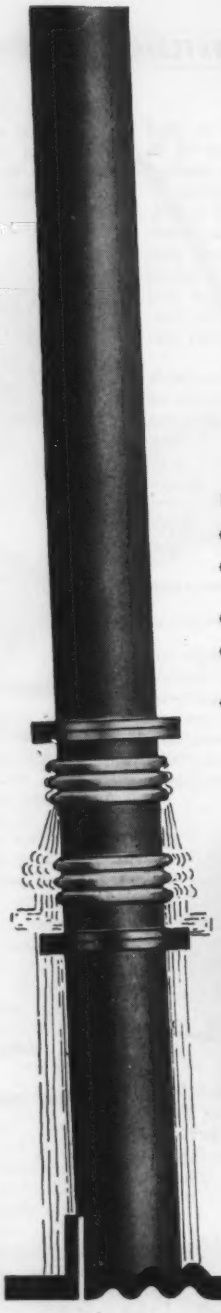
EMD 319 for further information



When PIPES MOVE

in nuclear, chemical and gas plants and in marine engineering, where pipes are subject to extreme heat, movement must be effectively and efficiently absorbed. The ideal medium in the past few years has been found in the Stainless Steel Bellows Type Expansion Joint.

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- Maximum durability.
- Teddington convolution design ensures flexibility with strength.
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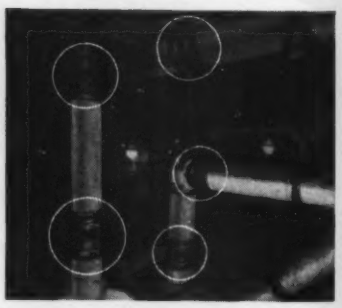
Teddington Bellows are produced in technical collaboration with the Solar Aircraft Co. U.S.A.



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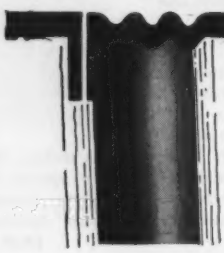
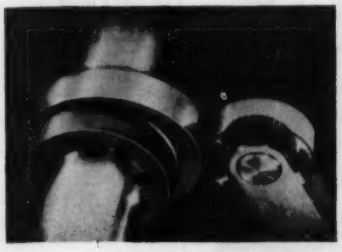


TEDDINGTON
AIRCRAFT CONTROLS LIMITED
INDUSTRIAL BELLOWS DIVISION
Ammanford, Carmarthenshire. Ammanford 455

Needle Cam Follower



A special range of Nadella needle cam followers, which are compact and robust, is now available. The outer rings are reinforced to serve directly as followers and can be supplied with cylindrical or convex surfaces.

Standard sizes range from 0·748 in. to 2·44 in. outside diameter. The larger sizes are available complete with inner ring and oil hole. Insley (London) Ltd.

EMD 383 for further information

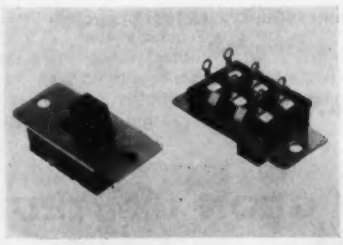
Magnetic Chuck

The latest addition to the Fimax range of universal, permanent, magnetic chucks has been produced for use on horizontal, vertical and jigboring machines, large surface grinders, mills, etc. It has a 14 × 12-in. chuck mounted so as to tilt about one lower corner and also to rotate about a vertical axis. The tilting movement is controlled by a screw-operated link motion. The chuck body, with its large-diameter supporting trunnion and two sine rollers, forms a 10-in. sine bar so that angles about the horizontal axis may be set accurately. Panton & Webb.

EMD 384 for further information

Miniature Slide Switches

A range of miniature slide switches is now available for radio, television and instrument applications and other small applications. These measure 1¼ × ¼ × ⅞ in. overall, with balanced, self-cleaning, low-resistance contacts. All current-carrying parts are silver plated. They are rated at 1 amp. 250 volt, a.c., or 0·25 amp. 250 volt, d.c. Insulation resistance will withstand a flash test of 2,500 volts



a.c. between frame and any contact for one minute without breakdown. The switches are suitable primarily for fixing at the back of the panel, but may also be chassis-mounted. Arcolectric Switches Ltd.

EMD 385 for further information

Conveyor Drive and Control Device

This unit is the latest addition to the range of Mardrive worm reduction units and incorporates a dustproof solenoid-actuation feature and a Crompton Parkinson 0·95-h.p. totally-enclosed, fan-cooled motor. Used in conjunction with the reduction unit, the motor provides a low output shaft speed well suited to conveyor drive and similar industrial uses.

As well as being able to stop and start as many as 100 times per minute, this latest unit facilitates the remote control of a conveyor system and allows the minimum number of operatives to be in attendance.

Whereas conveyors are normally driven at a constant speed consistent with the number of operatives concerned, a conveyor using the Mardrive unit can not only be driven at a much higher speed than normal, but when some form of micro-switching is coupled to the clutch-actuating solenoid, the conveyor can also be arranged to stop and start at predetermined points. Marine Engineering Co. Ltd.

EMD 386 for further information

Plastics-coated Copper Tube

Kuterlex tubing comprises normal high-quality copper tubing to B.S. 659: 1955 or B.S. 1386:1957 sheathed with a seamless polyethylene or p.v.c. cover. The sheathing fits tightly on to the copper and the use of Kuterlex is said to relieve the gas or water fitter of the work of wrapping long lengths of tubing. Where long lengths are involved for underground water pipelines, they can be laid by mole plough without trenching.

It has all the qualities of normal copper tubing with the added advantage of presenting a continuous protective surface to surrounding corrosive materials. Another application which presents itself is for industrial pipelines installed in corrosive atmospheres. Yorkshire Imperial Metals Ltd.

EMD 387 for further information

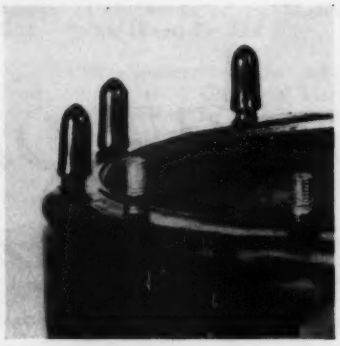
Coolant Clarifiers

Now available from stock is a new range of coolant clarifiers, the heart of which is a magnetic drum of unique design called the Magna-Drum.

As a result of the development of ceramic magnetic materials, it has become possible to produce a drum which is highly magnetic over its entire surface—a distinct advance upon conventional drums which normally use horseshoe-type magnets cast in steel and encased in a non-ferrous cylinder. The Magna-Drum has no such enclosure to restrict its magnetic field. Furthermore, it is claimed that its magnetic field is so intense and the fluid to be filtered so controlled that a high proportion of grinding abrasive is always contained in the swarf collected on the drum's surface. The swarf is removed by specially-designed scrapers. Philips Electrical Ltd.

EMD 388 for further information

P.V.C. Masking Caps



Flexible p.v.c. caps are now being supplied for masking threads during painting to prevent costly retapping operations. The caps, which are solvent resistant, can be colour coded for size and are available from 6 B.A. up to 3 in. in diameter in any reasonable length. Durable Plastics Ltd.

EMD 389 for further information

Sealing Device

Bellafram seals are long-stroke, deep-convolution, constant area diaphragms, which are free positioning with complete relaxation within their stroke. They are responsive to small pressure changes, and have virtually no mechanical spring gradient and possess extremely long stroke and flexing life. They perform the functions of both bellows and diaphragm (hence the name), but are claimed to have advantages over both.

They are precision moulded from high-grade oil- and heat-resistant synthetic rubbers, reinforced with high-tenacity fabric materials.

The seals are not intended as substitutes for conventional hydraulic packings, but are designed to meet a specific need, i.e., for a seal with a virtually frictionless action, and 100 per cent sealing efficiency. Uses for which it is intended include thermostatic valves, pressure volume transformers, pressure regulators, pressure switches, dash pots, mixing valves, remote positioners, balanced valves, fluid barriers, etc. Geo. Angus & Co. Ltd.

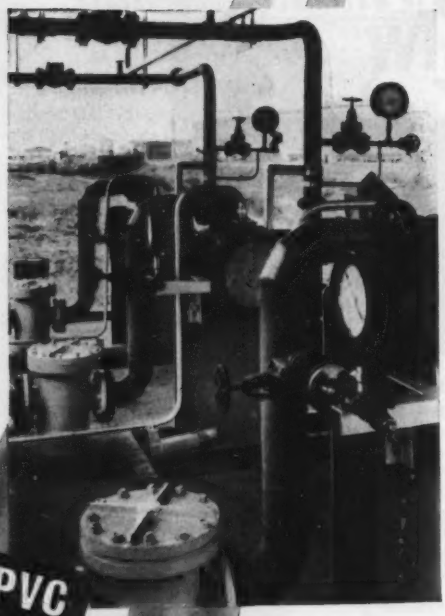
EMD 390 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

GEON RA 170

the High Impact PVC



High Impact PVC tubing made by Extrudex Ltd, Bracknell, using Geon RA170. Photographs taken at The British Petroleum Co. Ltd Refinery, Isle of Grain.

Geon is a registered trade mark.

pipes acid effluent safely

Day and night, night and day, 11,000 feet of shatter-proof piping made with Geon RA170 High Impact PVC carries acid effluent safely away from the BP oil refinery on the Isle of Grain.

Geon RA170 was chosen because it combines outstanding toughness—15-times that of ordinary PVC—with high tensile strength, lightness and resistance to chemicals and solvents. No other PVC so completely satisfies the requirements of piping for the petroleum industry, the chemical industry and all branches of civil engineering.

Please write for Booklet No. 160

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News of Industry

New appointments by Metropolitan-Vickers Electrical Ltd. include those of **Mr. C. F. Saunders,** to be chief engineer, standards department; **Mr. G. H. Moule,** as chief engineer, heating and welding department; **Mr. F. Crowther,** as assistant chief engineer (design), industrial control department.

Mr. H. I. Wood has been appointed chief engineer, turbo-generator department, at Trafford Park, and **Mr. F. R. Harris,** chief engineer, gas turbine engineering department, of the A.E.I. turbine-generator division.

Mr. C. T. Wilkins, chief designer at Hatfield of the de Havilland Aircraft Co., has been appointed to the board and to be chief designer of the company as a whole. **Mr. R. E. Bishop,** design director of the company, is now appointed deputy managing director. **Mr. R. M. Clarkson** has been appointed research director.

Mr. W. J. Hopkins recently relinquished his position as managing director of Simon Engineering Companies of Canada and has returned to Cheadle Heath in charge of research and development for Simon Handling Engineers Ltd. **Mr. M. E. Hornback,** until recently chief mechanical engineer to Aluminium Co. of Canada, has been appointed director and consultant for Simon's Canadian company.

Mr. R. W. Ward, deputy technical director of Gloster Aircraft Co., has joined Avro's weapons research division as chief development engineer.

Mr. Donald Clark has joined Distington Engineering Co. Ltd. as a designer of mining equipment.

Mr. J. W. Plowman (Dewrance & Co. Ltd.) has been re-elected chairman of the British Valve Manufacturers' Association for the coming year.

Mond Nickel Fellowships for 1958 have been awarded to **Mr. G. H. Longworth** (Lancashire Steel Manufacturing Co. Ltd.), **Mr. J. C. Morrison** (Carron Co.) and **Mr. T. Tait** (Colvilles Ltd.).

Dr. D. F. Galloway, director of P.E.R.A., was elected vice-president of the International Institution for Production Engineering Research, when the organisation recently held its general assembly in Britain for the first time.

The **Blackburn Group** of companies is to establish a new organisation in Yorkshire to design, produce and market electronic equipment for commercial applications. It will be known as the commercial electronics department. Manager will be Dr. H. Fuchs.

The Birmingham Exchange and Engineering Centre has announced that, to avoid the inference that it is an exhibition of local firms only, it will in future operate under the name of **The Engineering Centre.**

As part of the long-term reorganisation of the A.E.I. group, **Siemens Edison Swan Ltd.** are to be divided into three divisions: cables, telecommunications and radio, and electronic components.

The Consultant Designers Group, a specialist group within the Society of Industrial Artists, recently held an exhibition at the Design Centre in London to demonstrate the part which can be played in industry by the consultant designer.

The **National Council for Technological Awards** is proposing the creation of a new award which will be higher than the Diploma in Technology, with the object of offering facilities for carrying out original investigations related to the needs of industry. A College of Technologists will be established by the council, and the award will take the form of Membership of that College (M.C.T.).

A new ring rolling mill has been opened at Netherton, Worcs., by **N. Hingley & Sons Ltd.** The company produces light section rings in a range of non-ferrous metals, stainless steels, alloy and carbon steels.

Latest of the **Kelvin Hughes** ultrasonic flaw-detection equipment is being displayed in a mobile demonstration unit of the company which has been touring U.K. industrial areas during December.

Polypropylene is now being made available in the U.K. by **Shell Chemical Co.,** the first opportunity the British plastics industry has had to examine this material. Supplies, which are at present limited, will be sold under the trade name of Carlona and are intended for evaluation in the injection-moulding field.

Latest type of fully-automatic zinc and cadmium-plating plant has recently been installed at the works of the **Modern Electro Plating (Kent) Co. Ltd.**

London headquarters of the **A.E.I. Group** are now at 33 Grosvenor Place, S.W.1. Telephone number is BELgravia 7011. Among members of the group now in the new premises are Metropolitan-Vickers Electrical Co. and British Thomson-Houston Co.

A new organisation, **Hydraulic Components Co.,** has been set up to produce and market oil-hydraulic equipment (valves, pumps, fittings and accessories) of improved design. More details are to be made known later.

The **Society of Engineers** has, with effect from December 15, moved to new offices at Abbey House, Victoria Street, London, S.W.1. Phone number is unchanged.

Mr. S. P. Woodley, general manager, Vickers-Armstrong Aircraft Ltd., will discuss the impact of the aircraft industry on other industries at the **Seventh Aircraft Production Conference** which will be held at Southampton on April 16 and 17 by the Institution of Production Engineers.

The **A.E.I. Group** has recently held a three-day conference of design engineers and draughtsmen to discuss the closer integration of engineering and styling, and analyse the design of recent products made by members of the group. Organised by the group's appearance design sub-committee under the chairmanship of Mr. R. M. Kay, the conference attracted some 60 delegates and visitors who were addressed by speakers from within the company and by Sir Gordon Russell, director of the CoID.

Designer's Diary

Dec. 31. I.E.E. Christmas Holiday Lecture: "Invention and New Machines". Savoy Place, London, W.C.2. 3 p.m.

Jan. 7-9. Villiers Engineering 60th Anniversary Exhib. New Horticultural Hall, London, S.W.1.

Jan. 12. Inst. of Eng. Designers. "Design in Relation to Production of Castings". 6 Higham Place, Newcastle. 7.15 p.m.

Jan. 13. R.Ae.Socy. Lecture: "Stress Corrosion". 4 Hamilton Place, London, W.1. 7 p.m.

Jan. 19-22. Physical Society Exhibition of Scientific Instruments. Horticultural Halls, London, S.W.1.

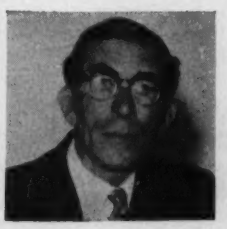
Jan. 20. Plastics Inst. "Fluorine-containing Polymers". 183 Euston Road, London, N.W.1. 6.30 p.m.

Jan. 21. Plastics Inst. "Melamine Resins and their Applics." Eldon Grill, Grey Street, Newcastle. 7 p.m.

Jan. 27. R. Ae. Socy. Lecture: "Noise Problems in Engine Design". 4 Hamilton Place, London, W.1. 7 p.m.

H. I. Wood

F. R. Harris



W. J. Hopkins

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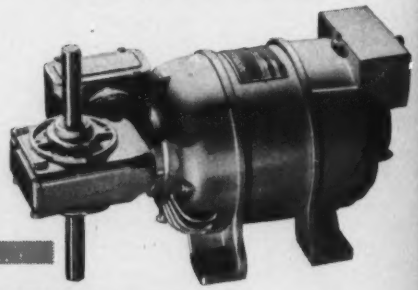

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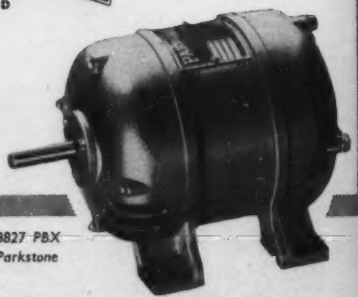

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